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PHYSICAL SIMULATION SUPPORT TO THE CREWMAN'S ASSOCIATE CONTROLLER SOLDIER TRACKING AND SLEWING EXPERIMENT USING THE RIDE MOTION SIMULATOR

DECEMBER 1995

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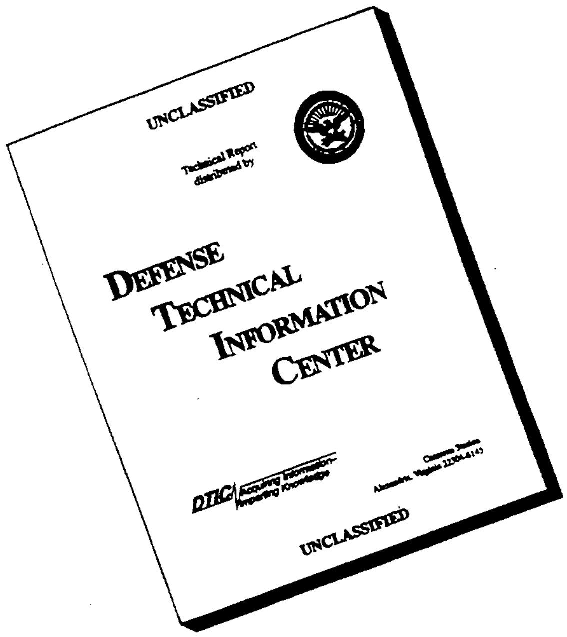

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13. ABSTRACT (*Maximum 200 words*)

This report describes and documents only the work performed by the Physical Simulation Team in the Physical Simulation Laboratory using the Ride Motion Simulator (RMS). The Physical Simulation Team conducted an experiment using the RMS for the Crewman's Associate Team along with the Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL) to examine soldier performance using a flat panel display and two controllers while in a motion environment. The purpose of this study was to measure and compare turret slewing and tracking performance with the conventional, displacement yoke used in the M1 tank, and a fixed yoke incorporating a thumb-operated tracking control. This report does not incorporate the findings of ARL, it only represents the work done on the RMS during these tests. The tests were jointly executed by the Simulation Area (AMSTA-TR-D) and ARL, in Building 215, at TARDEC from 16 October to 9 November 1995.

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PREFACE

This report documents the work performed from June - December 1995 in the Physical Simulation Laboratory (PSL) for the Ride Motion Simulator (RMS) by the Physical Simulation Team. Questions regarding the Ride Motion Simulator are to be referred to the U.S. Army Tank-automotive Research, Development, and Engineering Center (TARDEC), ATTN.: Physical Simulation Team (AMSTA-TR-D), Bldg. 215, Warren, MI 48397-5000, Telephone: AUTOVON/DSN 786-6676, Commercial (810) 574-6676, FAX (810) 574-8667.

Special thanks goes out to those who played an important role in the many facets of this study. Some of whom include: Ronald Smith, mechanical technician, who fabricated the mounting fixtures to hold the flat panel display and the two controllers; John Weller, mechanical engineer, for his work running the many DADS models of the M1A1 tank; Alexander Reid, electrical engineer, for his support in data analysis programming; Aleksander Kurec, mechanical engineer, who worked out many of the mechanical details for the mounting fixtures; Victor Paul, electrical engineer, who was responsible for data formatting and archiving; George Norkus, and Elmer Donajkowski, mechanical technicians, who maintained the simulator; and Thomas Ashworth, electrical technician, who aided in the characterization of the RMS.

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1.0 INTRODUCTION

The Crewman's Associate Advanced Technology Demonstration (CA ATD) Team is developing an Advanced Technology Demonstrator (ATD). This CA ATD program is a coordinated effort to demonstrate, through modeling and soldier-in-the-loop interactive simulators, crew station concepts utilizing advanced displays and controls which will enable soldiers to quickly understand and easily react to large amounts of information. One of the objectives of the CA program is to develop a crew station that ensures a reduced crew can fight as effectively as a four-man crew by providing improvements in control-display design and their interface with the soldier. This crew station will be integrated into the Future Main Battle Tank.

The CA ATD Team, of the U.S. Army TARDEC, has requested that the Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL) in Aberdeen Maryland, conduct research examining soldier performance using candidate displays and input-output devices in the motion environment to which the vehicle and the crew will be exposed. ARL's responsibilities included drawing up a test plan, analyzing the human performance data, and coming up with some conclusions. This is the first in a series of studies that are planned by the HRED in support of the goals of the Crewman's Associate program. The purpose of this study was to measure and compare turret slewing and tracking performance with the conventional, displacement yoke used in the M1 tank, and a fixed yoke incorporating a thumb-operated tracking control.

The CA ATD Team (AMSTA-TR-R) directed the Physical Simulation Team of the Development Business Group (AMSTA-TR-D), of the U.S. Army TARDEC, to conduct this experiment using the TARDEC Ride Motion Simulator (RMS). The RMS is fundamentally a platform mounted in a framework so that four motions (four degrees of freedom) can be imparted to it simultaneously (see Figure 1.) The motions are generally oscillatory in nature and comparable to the motions that might be experienced in the crew compartment of a wheeled or tracked vehicle under mild to severe operating conditions. A wide range of vehicles, bump courses, and seatings (gunners, commanders, drivers) can easily be simulated and recreated on the RMS. The CA ATD Team was responsible for the software that created the displays seen by the soldiers and recording their performance data. The Physical Simulation Team was responsible for conducting the experiment using the RMS, drive file development, and collecting simulator and soldier performance data.

This report describes and documents the work performed in the Physical Simulation Laboratory (PSL) for the Ride Motion Simulator by the Physical Simulation Team. This report does not incorporate the findings of ARL or the CA ATD Team. The tests were jointly executed by the Physical Simulation Team, the CA ATD Team and ARL, in Building 215, at TARDEC from 16 October to 9 November, 1995.

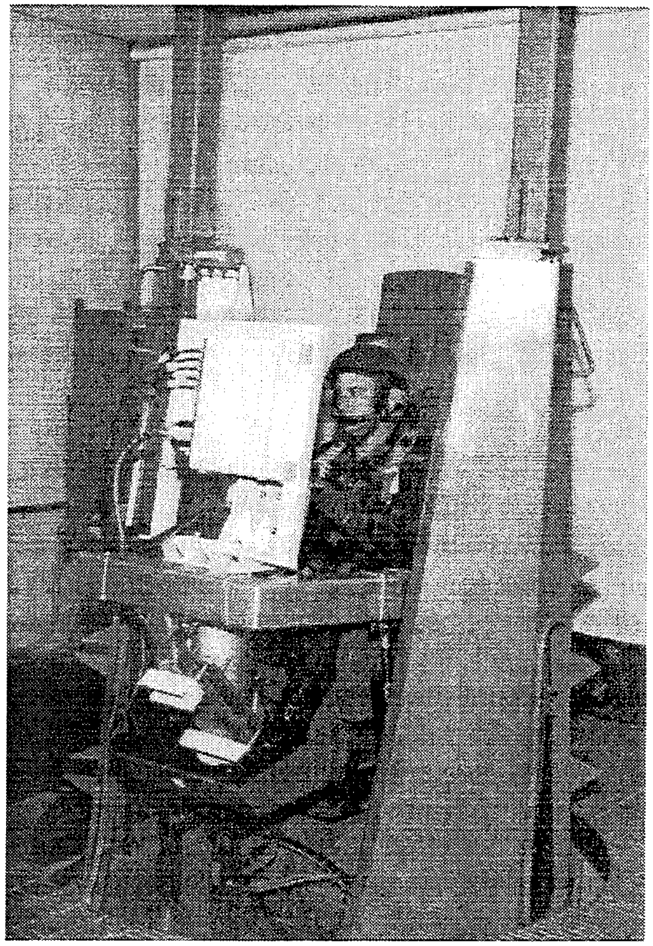


FIGURE 1. RIDE MOTION SIMULATOR

2.0 OBJECTIVES

The purpose of this laboratory experiment was to measure and compare the effects of vehicular-induced vibration on turret slewing and tracking performance using a new Lear fixed yoke handle (controller) with thumb-operated control versus the conventional, displacement controller used in the M1A1 tank. Both controllers were used to position the gunner's crosshairs and track targets. During this study, this new Lear thumb-operated controller permitted firing the trigger on the left handgrip. Each controller was mounted on the RMS in such a way that the task of swapping them was minimal. The "turret" slewing and target tracking tasks that were performed were presented on a flat panel, liquid crystal display (LCD). The size of the display was 6 x 9 inches with a resolution of 480 x 640 lines. This monitor was mounted to the RMS about 20 inches in front of the subject. A total of 30 combat vehicle crewmen from Ft. Knox, KY and armor crewmen from Aberdeen Proving Grounds (APG), MD served as subjects. The Military Occupational Specialty (MOS) of these subjects were 19K (armor crewmen). All were right-handed and met visual acuity requirements of 20/20 in one eye and at least 20/100 in the other (corrected or uncorrected).

The results of this study will assist in the design, assessment, and selection of a multi-function controller for Crewman's Associate and ultimately the Army's Future Main Battle Tank. Refer to the Addendum Test Plan for a thorough background and explanation of the research.

3.0 CONCLUSIONS

The RMS was successful in reaching the objective of this experiment. Thirty soldiers were tested, fifteen on a thumb-operated Lear controller and fifteen on a conventional displacement yoke. All motion data were recorded and analyzed per the test plan.

The tests involved the comparison of soldier interaction with the two different controllers being tested in a simulated vehicle motion environment. All subjects were trained at no motion and four ride levels to become familiar with the motion base and controller tasks. During testing, the subjects completed two iterations each of the no motion and four ride levels of motion for a total of 10 simulations. The order of presentation to each soldier of the ride levels was counterbalanced as shown in Table 1.

The RMS availability rate was 100% throughout the 4 week experiment as there were no ride simulator failures or down time. This was due in part to proper maintenance procedures before the test period, and careful test preparation. The simulator was safety certified before commence of test. The successful completion of this experiment once again proved the simulator can be effectively utilized for soldier-in-the-loop simulations at TARDEC at a lower cost than contractor operated or proving ground facilities.

The Physical Simulation Team performed all modeling, simulation, data acquisition, operations, and analysis tasks using only the resources of this Team. Therefore, all data and information gathered from this experiment will be archived only at one location to ease re-use and investigation into future crewman and crewstation studies.

An analysis was performed on the ability and repeatability of the motion base to create the ride dynamics of the M1 tank which is was used to simulate the Future Main Battle Tank (FMBT). The simulator performed its intended tasks within a standard deviation of less than one-hundredth of a gravity (g) acceleration. This means that each soldier was subject to identical ride level dynamics, as intended. These ride levels ranged from secondary roads to moderate and rough cross-country travel. Thus, accurate, analytical comparisons of soldier performance with the two different controllers can be made with a high degree of confidence.

The results of this study will assist in the design, assessment, and selection of a multi-function controller for the Crewman's Associate program and ultimately the Army's Future Main Battle Tank.

TABLE 1. COUNTERBALANCING SCHEME

CONTROLLER		ITERATION	
A(Lear)	B(yoke)	1	2
Subjects		Ride Levels (1-4)	
1	16	4 2 3 1	1 2 4 3
2	17	2 3 4 1	4 3 2 1
3	18	2 1 4 3	1 4 2 3
4	19	3 2 1 4	2 1 3 4
5	20	3 1 2 4	3 2 4 1
6	21	1 3 2 4	4 3 1 2
7	22	4 2 1 3	2 3 1 4
8	23	2 4 3 1	3 4 2 1
9	24	1 3 4 2	1 2 3 4
10	25	4 1 2 3	4 1 3 2
11	26	1 4 3 2	2 4 1 3
12	27	3 4 1 2	3 1 4 2
13	28	1 4 3 2	3 1 2 4
14	29	2 1 3 4	1 4 3 2
15	30	3 2 4 1	2 3 4 1

4.0 RECOMMENDATIONS

We recommend that further work on crew-machine interfacing be done using the RMS. This particular test created a foundation for short and long-term motion base experiments involving soldier-machine interfacing. Due to the specific nature of this test environment, it is recommended that similar testing be considered since all subsystems are currently in place and operational. Some of the subsystems include the mounting fixtures for the flat panel display and controllers, and the data acquisition and instrumentation systems. For these reasons, the RMS is ready for additional testing to resume upon request.

The RMS is planned to undergo a major modernization beginning in 1996. The plans involve replacing the existing RMS with a new state-of-the-art RMS which will offer greater flexibility in test configurations through high modularity, networking to other simulators through the Defense Simulation Internet, computers, and modern digital programming techniques. The new simulator will make it possible to support a variety of next-generation/future system concepts and maintain long-range plans for developing unique tank-automotive technologies. One customer-desired feature is to employ re-configurable seating orientations including reclined-seating driver stations. The new ride simulator will utilize computer generated imagery for realistic displays of battlefield and target environments. It will have an inertial measurement unit package inherent to the simulator which will provide easy access for simulator positions, rates, accelerations. It was evident that some low-level input distortion was apparent throughout this experiment. The new simulator will eliminate this distortion through the use state-of-the-art servo-controllers and actuators. Special vibration-hardened displays will be designed to increase the realism and fidelity of future soldier-in-the-loop studies. Other design features will include a remote location for the hydraulic power supply. Currently the hydraulics are located directly under the RMS. Operating the hydraulic power supply causes the noise level in the RMS room to reach values around the 80dba range, which is near the Occupational Safety Health Agency (O.S.H.A.) permissible exposure limit of 85 dba.

Some instrumentation and electronic improvements for the RMS will include a redesigned hazard control panel. The RMS has a Computer Automated Measurement and Control (CAMAC) hazard control panel which is part of the safety system. It was designed to protect humans from injury and valuable components from damage. Although this hazard control panel was operational for this test, several hours of troubleshooting prior to the test were required to make the panel operational. Our recommendation is to replace the hazard control panel by using in-house resources. The Physical Simulation Team will solicit potential RMS customers for their needs and simulator desires throughout the RMS modernization program.

All laboratory simulation experimentalists question the fidelity and validity of their work. This is often accomplished by considering a verification/validation/accreditation guideline. The M1 dynamics model developed for this work, which was necessary for the motion drive commands, has undergone some analytical verification and validation over recent years. This process primarily involved equation checking and comparison of simulation results to Proving Ground results. However, since this experiment involved the use of active U.S. Army M1 tank gunners and commanders, their verbal opinions through the use of a special questionnaire, on the realism of the ride, distributed to all subjects, would have proven valuable.

This experiment incorporated two data acquisition systems; motion base system designed by the Physical Simulation Team and human performance designed by the Crewman's Associate Team. As such, these systems used uniquely different software, hardware, and personnel to design and operate them. It is recognized that experiments arise where two or more data acquisition systems are required. When presented in this situation, it is preferred to design as much commonality to both systems in terms of software, hardware, and operations. This will ease data editing and analysis tasks greatly. The Physical Simulation Team recognizes this and will design new ride simulator data acquisition systems with this in mind. We recommend that the Physical Simulation Laboratory be tasked to design and operate all RMS program data acquisition systems if possible.

This experiment was successful because of the intense pre-test preparation performed by all participants. Several key meetings were held up to 5 months before testing to ensure the experiment design, timing of subject participation, and data collection and analysis were performed as planned. Adequate and realistic timelines and resources for all simulation development tasks is highly advised for simulation programs such as this one.

5.0 DISCUSSION/TESTING

5.1 System Description and Characterization

5.1.1 System Description

The RMS is a four-degree-of freedom simulator capable of recreating the ride of any army land-based vehicle. It is fundamentally a platform mounted in a framework so that four motions (four degrees of freedom) can be imparted to it simultaneously: linear motion along the vertical axis, rotational motion about the vertical axis (yaw), rotational motion about the transverse axis (pitch), and rotational motion about the longitudinal axis (roll). The motions are generally oscillatory in nature and comparable to the motions that might be experienced in the crew compartment of a wheeled or tracked vehicle under mild to severe operating conditions. The platform is large enough to allow simulation of a crew station, or to simply evaluate a seating configuration. Investigations can be conducted on human tolerance to vibrations in general, or task performance in a vibrational environment.

In the current configuration, the input signals are generated from computer data files created on a CRAY-2 supercomputer using computer simulation of an army vehicle operating over specific bump courses. These files are then modified and used to drive the RMS using a micro-VAX II computer. With this configuration, a wide range of vehicles, bump courses, and seatings (gunners, commanders, drivers) can easily be simulated and recreated on the RMS.

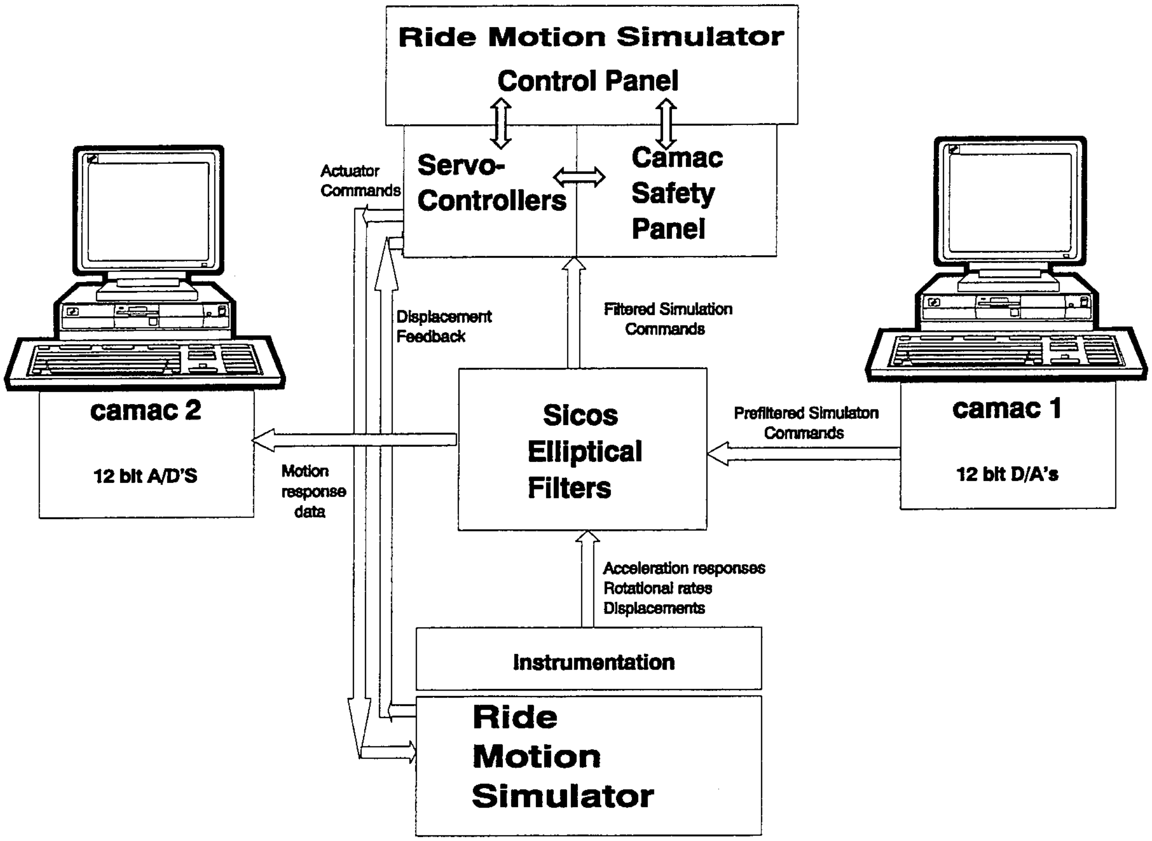


FIGURE 2. RMS SUBSYSTEMS

The RMS is comprised of the following subsystems (see Figure 2):

- -CAMAC System.
- -Servo-Controllers.
- -CAMAC Safety Panel.
- -Motion System.
- -Sicos Filters
- -RMS Control Panel.

The CAMAC computer system acts as an interface between a micro-VAX II computer and the RMS. Data files stored on the micro-VAX II determine the terrain profile, vehicle, and speed the RMS will simulate. These data files are output to the RMS through the CAMAC via a Digital to Analog Converter (DAC). This DAC converts digital values in a computer to voltages which are sent to the servo-controllers. The CAMAC has the ability to sample data (analog to digital converter), sense when a switch is thrown, and determine the presence of an applied voltage.
The servo-controllers receive the voltage commands from the CAMAC system, determine if it exceeds a preset limit, condition the commands, and then send them on to the electro-hydraulic servo-valves, which, in turn, power the RMS.

The pneumatic control panel provides the RMS operator access to the status and control of the pneumatic safety system and provides for a safe shutdown sequence in case of an abort.

The motion system of the RMS is electrically controlled and hydraulically powered. The power system is a self-contained, fully integrated system including controls, reservoir, pump, accumulators, manifolds, filters, and a water-cooled heat exchanger.

The hydraulic control panel provides the operator control of the hydraulic system.

For a detailed description of these subsystems, TARDEC report number 13464 titled "User's Manual for the Ride Motion Simulator, August 1989" can be referenced.

5.1.2 RMS Characterization

A number of characterization tasks were performed before the study was run to quantify the RMS performance characteristics. These tests were output sensitivity, tracking, bandwidth, displacement envelope, and maximum deceleration. These are defined as follows:

Output Sensitivity

This test determines the position accuracy and scale factor of the RMS. The RMS was input a dc voltage command and the resultant displacement in each axis was measured. A least-squares approximation equation was used to determine the scale factor, m. See equation 1.

$$m = \frac{n\sum(w_i v_i) - \left(\sum w_i\right)\left(\sum v_i\right)}{n\sum(w_i^2) - \left(\sum w_i\right)^2} \qquad (1)$$

where: v_i = output position measured
w_i = input voltage
n = number of data points

Applying equation 1, the scale factors are:

Roll:	0.934 vdc/deg
Pitch:	0.796 vdc/deg
Yaw:	1.024 vdc/deg
Vertical:	0.318 vdc/inch

Non-linearity was calculated using equation 2.

$$\frac{(m)(w_i)-(v_i)}{(m)(w_i)} * 100\% \qquad (2)$$

where:

v_i	=	output position measured
w_i	=	input voltage
m	=	slope measured from equation 1

Non-linearity was calculated at a few points for each axis and the results are:

Roll:	<	10%
Pitch:	<	4%
Yaw:	<	6%
Vertical:	<	8%

Tracking

Tracking tests were performed to indicate the low-level input distortion of the RMS. Full scale inputs at 0.1 Hz were input into each axis. The three rotational rates and vertical accelerations were recorded on a strip chart recorder.

The angular axes exhibited no appreciable mis-tracking or distortion; however, the linear (vertical) axis exhibits acceleration noise of up to 0.10 g max.

Bandwidth

Bandwidth determines the range of frequencies faithfully output by the simulator. Frequency response of the RMS was measured at the -3db point and are expressed in hertz:

Roll:	9.0 Hz
Pitch:	9.8 Hz
Yaw:	2.0 Hz
Vertical:	6.3 Hz

Displacement Envelope

The displacement envelope of the RMS is the full-scale displacement of each axis. The electrical limits are adjusted for safety purposes. The values are shown below:

Roll:
Physical limit: +/-10.5 degrees
Electrical limit: +9.8, -8.5 degrees

Pitch:
Physical limit: +/-12.5 degrees
Electrical limit: +9.1, -12.3 degrees

Yaw:
Physical limit: +/-9.8 degrees
Electrical limit: +9.7, -10.6 degrees

Vertical:
Physical limit: +/- 20 inches
Electrical limit: +11.6, -12.2 inches
Pneumatic limit: +/- 12.5 inches

Maximum Deceleration

Tests were performed to determine the maximum runaway acceleration of the simulator. These tests were performed to ensure the runaway accelerations were within permissible values, based on the Bioastronuatics Data Book by Dr. Richard G. Snyder of the University of Michigan. A vertical accelerometer was used to determine the maximum vertical deceleration. Angular rate transducers were used to determine the maximum angular rates which were used to calculate accelerations. The procedure was to input a full scale step input to each axis independently, and then measure the rates and acceleration. The deceleration values for the RMS were measured to be:

Roll: -11.1π rad/sec^2
Pitch: -20.4π rad/sec^2
Yaw: -5.0π rad/sec^2
Vertical: -5.6g

All the above tests were conducted to ensure that the RMS motion envelope was correct and met the test plan requirements.

5.1.3 Modeling

The RMS was programmed to reproduce rides imparted to the gunner in an M1 tank. The simulated terrains used were reproductions of automotive test courses at Aberdeen Proving Grounds (APG) in Aberdeen, Maryland and Waterways Experimental Station (WES) in Vicksburg, Mississippi. Table 2 contains the simulated terrains used along with their chosen speeds. The speeds chosen represent typical traversing speeds over these courses. The terrains were chosen to provide realistic simulated M1A1 vehicle dynamic motion. These terrains are categorized as being mild (Ride Level 1) to severe (Ride Level 4).

A high resolution computer-based dynamics modeling method called Dynamic Analysis Design System (DADS) was used to determine the simulation commands for the RMS. The model used is a rigid body mathematical representation in three dimensions of an M1A1 tank. The model produces kinematic and dynamic parameters such as vertical position and acceleration at specified vehicle locations such as the crewstation. The forcing function input to the model was the selected courses at the speeds in Table 2.

An alternative method for determining the RMS drive commands is to use field or proving ground recorded data and "play" these data into the simulator. This method can produce accurate simulator motion dynamics but was not chosen for a number of reasons mainly due to extensive cost and time required for an instrumentation and data collection task. However, the DADS computer-based methodology chosen yields results good enough for this experiment. It produced resultant transient-dynamics of the M1 suspension system accurately from frequencies ranging from near zero to about 3 hertz. These frequencies cover the primary pitch, vertical, and to a lesser extent, yaw and roll amplitudes. DADS, being a rigid body modeling methodology, does not replicate the dynamics associated with higher component frequencies such as track pad slap. However, the motion base's response would not permit frequencies much above 3 hertz as noted in Section 5.1.2. and thus any vibration components due to powertrain, track slap, or turret basket resonances would be sharply attenuated by the RMS and not felt by the soldier. It was noted, although not documented, that throughout the experiment the soldiers believed the simulator ride was realistic and representative of the M1 tank.

The goal was to find four testing ride levels that had equal "step ups" between them as well as the most severe ride (Ride Level 4) not exceeding 6 watts of average absorbed power. This value is considered an upper acceptable limit for comfort for off-road vehicles (Lee & Pradko, 1968). This was difficult and time consuming since whenever a "new" simulation was run using the above method, steps needed to be followed for this new terrain to determine the average absorbed power for it. These steps included filtering the commands to a usable range and testing it out on the simulator to verify ride comfort requirements. The requirement also consisted of producing a training ride level that was characteristically different than the test ride levels but its absorbed power or ride comfort between ride levels 2 and 3. This training ride level was the LET6 terrain. The absorbed power, frequency and amplitude of vertical acceleration of all the terrains is shown in Table 3.

TABLE 2. SIMULATED TERRAINS

RIDE LEVEL	TERRAIN	SPEED
1	Perryman A (APG)	40 mph
2	Perryman 3 (APG)	10 mph
3	Churchville B (hilly cross-country) (APG)	12 mph
4	Perryman 2 (cross-country) (APG)	23 mph
2.5	Letourneau 6 (WES)	10 mph

TABLE 3. TERRAIN CHARACTERISTICS

TERRAIN	TOTAL ABSORBED POWER (watts)	DOMINANT FREQ. (Hz) (of vert. accel)	AMPLITUDE (g rms) (of vert. accel)
Perryman A @ 40mph	0.1	1.3	0.05
Perryman 3 @ 10mph	0.5	1.3	0.10
Letourneau 6 @ 10mph	0.7	1.3	0.10
Churchville B @ 12mph	1.2	0.7	0.13
Perryman 2 @ 23mph	2.8	1.0	0.25

5.1.4 <u>Data Acquisition</u>

This experiment employed the use of two data acquisition systems; a CAMAC based motion performance system designed by the Physical Simulation Team and a Silicon Graphics Inc. based soldier performance system designed by the Crewman's Associate Team. The CA Team collected turret slewing and tracking performance yet these results are not contained in this report. These systems used uniquely different software, hardware, and personnel to design and operate them. The purpose of the Physical

Simulation data acquisition system was to record motion simulator response data using linear accelerometers, angular rate transducers, and linear displacement transducers.

This suite of sensors provide the simulator operator and experimentalist with a complete record of simulator and ride motion responses. See Table 4 for the type of sensors used.

TABLE 4. TYPES OF SENSORS AND SIGNALS RECORDED

Location	Transducer	Axis	Manufacturer	Model	Scale Factor
RMS	LVDT	RMS Vertical	Schaevitz	25002XS-D	0.318 vdc/in
RMS	Potentiometer	RMS Roll	Markite	3583	0.934 vdc/deg
RMS	LVDT	RMS Pitch	Pegausus	237361	0.796 vdc/deg
RMS	Potentiometer	RMS Yaw	Comp. instr. corp.	R05	1.024 vdc/deg
Seat	Accelerometer	Vertical	Setra	141B	1.0 vdc/g
Seat	Accelerometer	Longitudinal	Setra	141B	1.0 vdc/g
Seat	Accelerometer	Lateral	Setra	141B	1.0 vdc/g
Seat	Rate transducer	Roll	Humphrey	RT0301081	12.4 mv/deg/sec
Seat	Rate transducer	Pitch	Humphrey	RT0301081	12.5 mv/deg/sec
Seat	Rate transducer	Yaw	Humphrey	RT0202011	42.1 mv/deg/sec
CAMAC	Start Pulse	n/a	CAMAC1	n/a	5.0 v = ON
SGI	Trigger Pull	n/a	SGI	340 VGX	5.0 v = ON
SGI	Target Appear	n/a	SGI	340 VGX	5.0 v = ON

The linear accelerometers produce the vertical acceleration data used in the calculations of absorbed power, amplitude, and frequency for every test run.

The rate transducers provide angular velocity recordings to ensure proper soldier motion cues. The displacement transducers provide the simulator operator with a recording to ensure the motion base was driven to specification.

Extensive calculations were performed to characterize the ride comfort data, see Section 5.5 for more information.

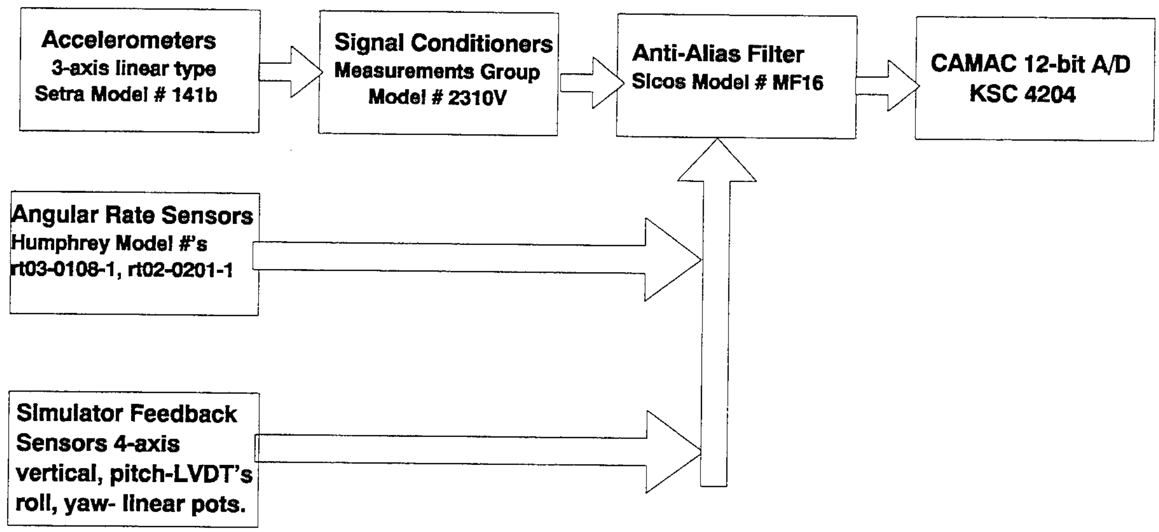


FIGURE 5. DATA ACQUISITION BLOCK DIAGRAM

The block diagram in Figure 5 illustrates the data acquisition system for the motion base and it contains the following:

Three axis accelerometers, rate transucers, and displacement transducers were installed on the motion base. Acceleration, rotational rate, simulator displacement data were recorded for each run.

The resolution of the angular rate sensors and the simulator feedback sensors was enough to be accurately sampled by the acquisition system; however, the relatively small output of the accelerometers required the use of signal conditioners to amplify the output to achieve a scale factor with higher resolution. Measurement Group signal conditioners used provided the excitation voltage, amplification and zero offset adjustment required by the accelerometers.

Acceleration, rotational rate and simulator displacement data were then low-pass filtered (40 Hz) using an anti-aliasing filter to remove any erroneous data subsequent when using digital data acquisition systems. The filtered response data is sent to the CAMAC data acquisition system where it is sampled at 100 samples/second. Data was recorded in files and one file was produced for every 2 minute simulation.

The accelerometers were mounted on the RMS seat approximately six inches below the seat cushion, and offset laterally four inches to the soldiers right. (See Figure 3). The ideal accelerometer placement should have been the subjects seat bottom, but given the limitations of the RMS framework, it was not feasible to do this, the rate transducer was mounted at the payload center of gravity and oriented to measure simulator yaw, pitch and roll rate. It can be seen from Figure 4 that the rate transducers were mounted on the RMS seat just behind where the soldier places his feet. The displacement transducers are inherently mounted to the hydraulic actuators of the motion base, and provide actuator displacement.

5.2 Safety System

The safety system is comprised of the following pneumatic and electrical interlocks to provide protection to test specimens and equipment:

Pneumatic Interlocks:

RMS operator actuated:	Master stop Pitch, Roll, Yaw stop Yaw stop Roll, Pitch stop
RMS automatically operated:	High limit (adjustable) Low limit (adjustable)
Soldier operated:	Emergency palm switch

Electrical Interlocks:

Servo-controller interlocks:	Roll (adjustable high and low limits) Pitch (adjustable high and low limits) Yaw (adjustable high and low limits) Vertical (adjustable high and low limits)
RMS operator actuated:	Cycle stop for roll/pitch/yaw controller Emergency stop for roll/pitch/yaw controller Cycle stop for vertical controller Emergency stop for vertical controller CAMAC emergency stop button CAMAC ramp down button
CAMAC (auto interlocks)	Roll (adjustable high and low limits) Pitch (adjustable high and low limits) Yaw (adjustable high and low limits) Vertical (adjustable high and low limits)

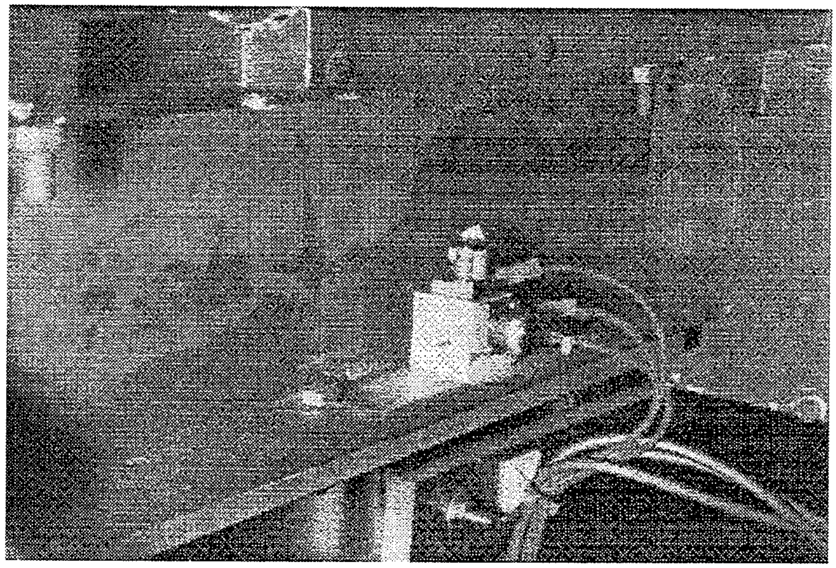


FIGURE 3. ACCELEROMETER PLACEMENT

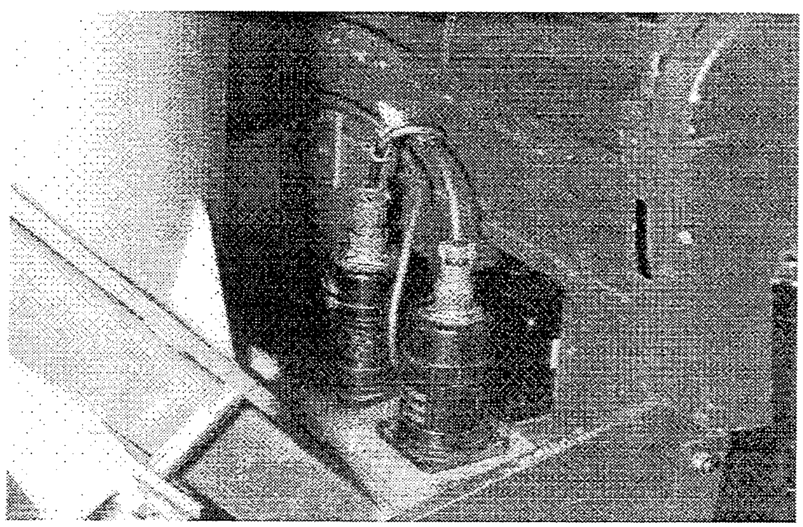


FIGURE 4. RATE TRANSDUCER PLACEMENT

The RMS is man-rated and undergoes a periodic review with the Human Use Committee (HUC) to document the progress of Human Research and Engineering Directorate (HRED) Research, Development, Test and Evaluation (RDTE) activities involving human subjects. The safety system of the RMS also includes an uninterruptible power supply (UPS) which is automatically activated in the event of electrical power failure. The UPS will provide the simulator with backup power for up to 30 minutes. In the case of an interlock detection, all simulator motion is stopped. A Failure and Effects sheet containing all the possible event failures with the RMS along with their necessary actions to be taken is completed and initialed off by the project engineer before every RMS test. For a full description of the safety interlocks, please see the TARDEC report titled "User's Manual for the Ride Motion Simulator, August 1989."

5.3 CA ATD Integration

Two different hand controllers were integrated onto the RMS as well as a flat panel display. A thumb-operated controller (model # AST-002) and a conventional displacement yoke (s/n 81579) were mounted to the platform of the RMS. These hand controllers were used to manipulate graphics on a flat panel display. The CA ATD Team provided the software which was used to provide the visuals on the flat panel display as well as record human performance data per the test plan. A Silicon Graphics (W6/4D/340VGX) computer was used to interface between the hand controllers and the flat panel display, taking input signals from the hand controllers and converting them to manipulate the graphics shown on the flat panel. Figure 6 shows a soldier, Lear handle, and a flat panel arrangement. Figure 7 is a block diagram showing the integration of the the two data acquisition systems. Half of the test subjects were tested on the thumb-operated controller and the other half on the displacement yoke while under motion.

FIGURE 6. FLAT PANEL DISPLAY AND LEAR CONTROLLER

5.4 Test Conduct

A total of 30 combat vehicle crewman from Ft. Knox, KY and armor crewmen from APG, MD served as subjects. The tests were conducted following the counterbalancing scheme layed out in Table 1. Fifteen of the 30 subjects were trained and tested on the fixed yoke controller and the other 15 subjects were trained and tested on the conventional yoke controller. Two subjects were run per day. The objective was to have one subject trained and tested on one control type in the morning, and the other subject trained and tested on the other control type in the afternoon. The control type tested in the morning of the first day was determined by random drawing. This control was tested in the morning of each odd day of test that followed, whereas the second control was tested in the morning of each even day. However, ESI handle problems arose through out the experiment which forced a change in this procedure. The soldier and controller selection was ultimately made by onsite ARL personnel. The tests were conducted per Table 5.

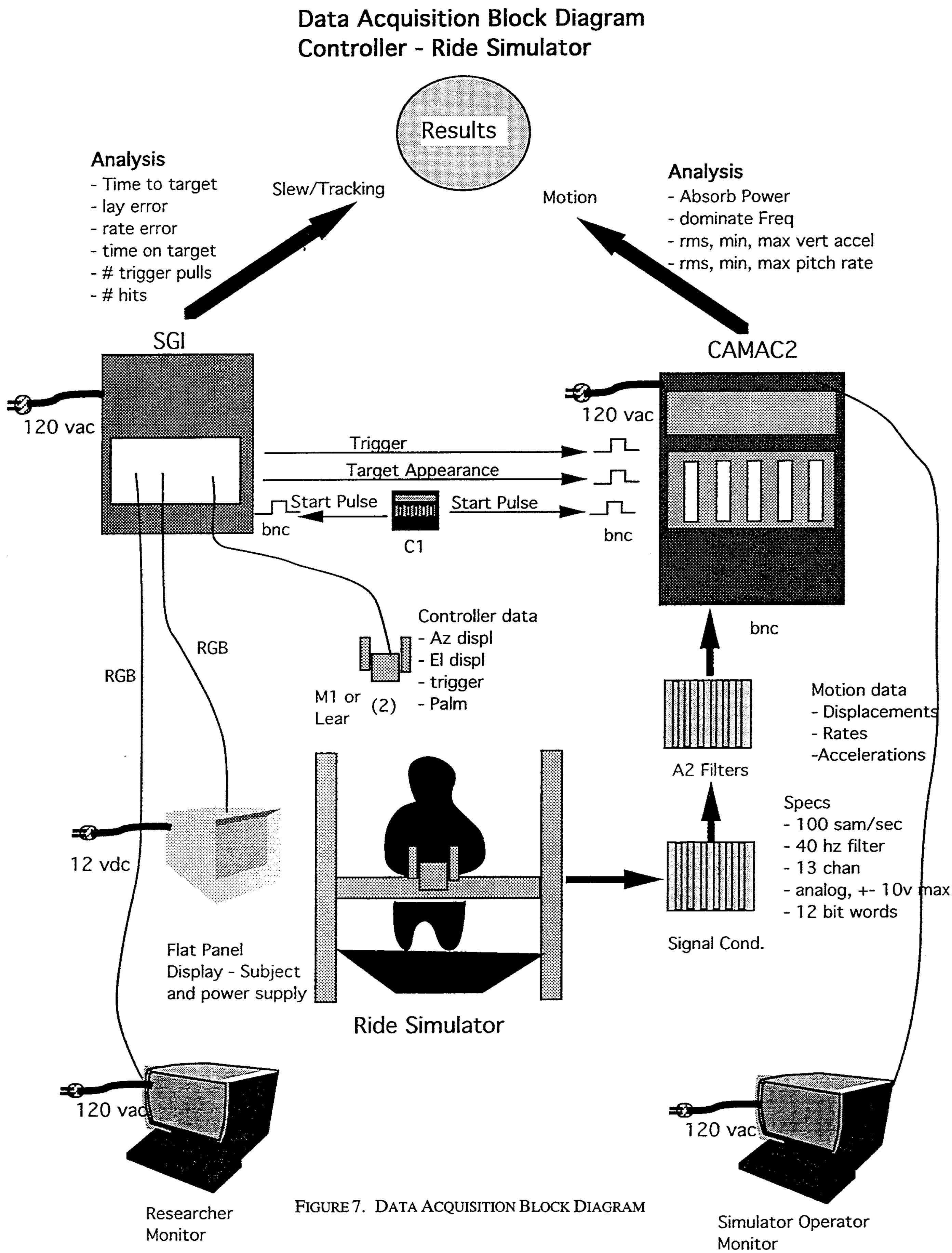


FIGURE 7. DATA ACQUISITION BLOCK DIAGRAM

TABLE 5. FINAL COUNTERBALANCING SCHEME

CONTROLLER A(Lear) Subjects	CONTROLLER B(yoke) Subjects	ITERATION 1 Ride Levels (1-4)	ITERATION 2 Ride Levels (1-4)	Date Tested	
1	16	4 2 3 1	1 2 4 3	10/17	10/17
2	17	2 3 4 1	4 3 2 1	10/18	10/26
3	18	2 1 4 3	1 4 2 3	10/20	10/30
4	19	3 2 1 4	2 1 3 4	10/19	11/08
5	20	3 1 2 4	3 2 4 1	10/23	11/02
6	21	1 3 2 4	4 3 1 2	10/23	11/02
7	22	4 2 1 3	2 3 1 4	10/23	11/08
8	23	2 4 3 1	3 4 2 1	10/24	10/24
9	24	1 3 4 2	1 2 3 4	10/26	10/30
10	25	4 1 2 3	4 1 3 2	10/27	10/30
11	26	1 4 3 2	2 4 1 3	10/27	11/08
12	27	3 4 1 2	3 1 4 2	11/01	11/01
13	28	1 4 3 2	3 1 2 4	11/03	11/03
14	29	2 1 3 4	1 4 3 2	11/02	11/03
15	30	3 2 4 1	2 3 4 1	11/09	11/09

For each control type, training and testing was first completed in the stationary or "0" ride level condition prior to training and testing in the four levels of ride motion. After instruction and practice in performing the turret slewing and target tracking tasks, the subject performed these tasks during consecutive runs until he attained an asymptote in time to target in the turret slewing task and time on target in the target tracking task. An asymptote was determined using the moving average technique. The subject then performed two test runs in the "0" ride level condition. After each of these test runs, the subject completed a questionnaire pertaining to his experience using their one particular controller.

After completion of training and test in the stationary condition, the subject then became familiar with performance of the turret slewing and target tracking tasks during one run at each of the four levels of ride motion, starting with the mildest ride (Ride Level 1) and graduating to the most severe ride (Ride Level 4). The subject then completed consecutive runs with LET6 until he reached an asymptote in time to target in the turret slewing task and time on target in the target tracking task.

The duration of each run at each ride level was 2 minutes in which the same 60 second ride was repeated twice. During the first minute of each run, the subjects performed the "turret" slewing task. During this period, a total of six targets were presented. Upon presentation of each target the crewman's task was to slew his crosshairs onto the target as rapidly and accurately as possible and depress the firing trigger.

During the second minute of each run, the subjects performed the target tracking task. Upon the presentation of three targets, the crewman slewed his crosshairs onto the target as rapidly and accurately as possible, and depressed the firing trigger. The subject was required to maintain his crosshairs on the target and pull the trigger as often as he was assured that he had achieved a good lay. He was instructed by Director of Combat Development (DCD), Ft. Knox, not to necessarily use center of mass when firing at the target.

5.5 Analysis

5.5.1 Introduction

This section presents an analysis of the motion data recorded for the entire experiment. The analysis was conducted primarily per the test plan and quantifies several key points;

a) It proves the simulation ride scenarios experienced by different soldiers were nearly identical in terms of motion.
b) It determines certain motion characteristics such as absorbed power during target acquisition and tracking tasks to quantify soldier performance.
c) It proves the ride simulator produced the intended motions as required by the test protocol.

The analysis was performed in both the time domain and frequency domain.

5.5.2 Statistics

Statistics were computed for each of the recorded motion file signals. The statistics are presented to quantify that the motion kinematics were repeated as intended for the entire experiment. This experiment contained scenarios of stationary (no motion) and ride motion conditions. Analysis of the no motion ride levels are omitted here as the simulator was stationary during these runs. Section 5.1.4 (Data Acquisition) showed that a data file is produced for every 2 minute simulation. These data files, F(t), were operated on to determine maximum, minimum, root-mean-squared, and standard deviation values. These values were then averaged over all test runs produced by all soldiers to summarize the performance of the motion base. The results of these calculations ensured the simulator produced the intended positions, rates and accelerations.

The average maximums were determined by equation (3)

$$A_{ave\max} = \sum_{1}^{n} \frac{MAX(F_i(t))}{n} \tag{3}$$

where F(t) = two minute motion data file
i = Ordinal file number ranging from 1 to 60
n = 60

The standard deviation of the maximums were determined using equation (4).

$$\sigma = \sqrt{\sum_{i}^{n} (MAX(F_i(t)) - A_{ave\max})^2 / n} \tag{4}$$

Table 6 presents an average of the maximum values of the ride simulator motion data. Each motion signal recorded is presented in the first column and the ride levels likewise presented in the top row. The entries represent the average maximum value and standard deviation of the maximum value for all soldiers. The test scenario was comprised of 30 soldiers each subject to 2 iterations per ride level. Thus, the average and standard deviation values are computed from sixty 2-minute data files for each entry. For further information on the operating scenario or ride level definitions, refer back to Section 5.1.3.

TABLE 6. AVERAGE MAXIMUM VALUES FOR ALL TEST RUNS

Motion Signal	Perryman A @ 40 mph Ride level 1		Perryman 3 @ 10 mph Ride level 2		Churchville B @ 12 mph Ride level 3		Perryman 2 @ 23 mph Ride level 4	
	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev
Vertical Position (inch)	1.29	0.01	8.28	0.01	7.96	0.01	8.80	0.06
Roll Position (deg)	2.94	0.01	0.92	0.01	0.93	0.01	3.22	0.02
Pitch Position (deg)	1.09	0.00	6.08	0.00	5.33	0.00	5.50	0.01
Yaw Position (deg)	6.96	0.01	0.05	0.01	0.07	0.02	8.27	0.01
Vertical Acceleration (g)	0.37	0.02	1.12	0.06	1.88	0.09	1.38	0.07
Longitudinal Acceleration (g)	0.08	0.03	0.12	0.01	0.22	0.04	0.38	0.10
Lateral Acceleration(g)	0.14	0.02	0.12	0.05	0.16	0.05	0.20	0.10
Roll Rate (deg/sec)	16.18	0.35	7.80	0.55	14.52	0.45	17.11	0.27
Pitch Rate (deg/sec)	8.17	0.16	32.14	0.22	36.91	0.25	30.81	0.60
Yaw Rate (deg/sec)	6.51	0.07	1.99	0.10	1.97	0.09	6.83	0.13

In a similar manner, the average minimums and standard deviations of these values of all the ride simulator test runs were calculated. These are presented in Table 7 and were computed using equation (5) and equation (6).

$$A_{ave\min} = \sum_{1}^{n} \frac{MIN(F_i(t))}{n} \tag{5}$$

$$\sigma = \sqrt{\sum_{i}^{n} (MIN(F_i(t)) - A_{ave\min})^2 / n} \tag{6}$$

TABLE 7. AVERAGE MINIMUM VALUES FOR ALL TEST RUNS

Motion Signal	Perryman A @ 40 mph Ride level 1		Perryman 3 @ 10 mph Ride level 2		Churchville B @ 12 mph Ride level 3		Perryman 2 @ 23 mph Ride level 4	
	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev
Vertical Position (inch)	-2.24	0.01	-4.75	0.01	-6.08	0.01	-9.23	0.02
Roll Position (deg)	-3.27	0.01	-0.61	0.01	-1.25	0.01	-3.73	0.02
Pitch Position (deg)	-1.79	0.00	-10.33	0.01	-10.33	0.01	-6.92	0.01
Yaw Position (deg)	-6.66	0.02	-0.07	0.04	-0.07	0.02	-8.25	0.02
Vertical Acceleration (g)	-0.37	0.02	-0.79	0.04	-0.64	0.03	-2.16	0.11
Longitudinal Acceleration(g)	-0.10	0.01	-0.23	0.05	-0.27	0.05	-0.38	0.10
Lateral Acceleration (g)	-0.10	0.02	-0.12	0.01	-0.17	0.03	-0.22	0.11
Roll Rate (deg/sec)	-14.84	0.24	-6.20	0.38	-8.37	0.27	-19.29	0.70
Pitch Rate (deg/sec)	-5.77	0.36	-38.44	0.48	-47.84	0.63	-34.92	0.42
Yaw Rate (deg/sec)	-7.10	0.05	-2.14	0.10	-2.53	0.07	-9.86	0.07

Table 8 presents the average root-mean-squared (rms) values and standard deviations of the rms entries. They were calculated by equation (7) and equation (8).

$$A_{averms} = \sum_{1}^{n} \frac{RMS(F_i(t))}{n} \tag{7}$$

$$\sigma = \sqrt{\sum_{i}^{n} (RMS(F_i(t)) - A_{averms})^2 / n} \tag{8}$$

TABLE 8. AVERAGE ROOT-MEAN-SQUARED VALUES FOR ALL TEST RUNS

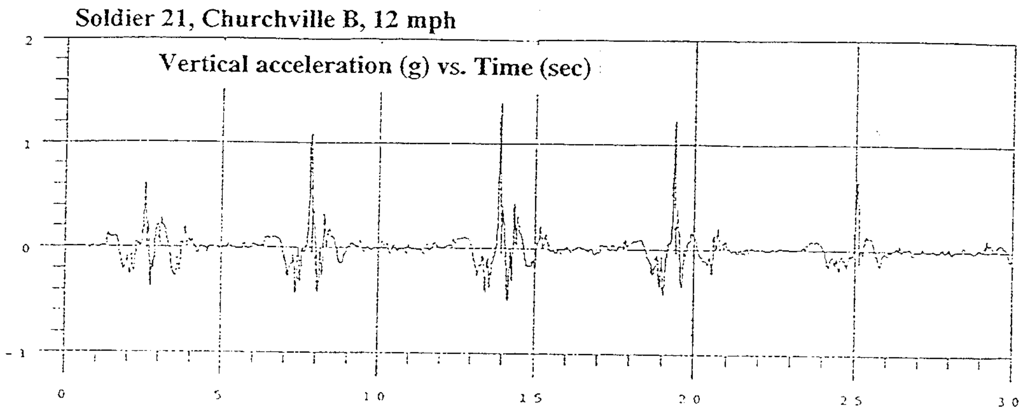
Motion Signal	Perryman A @ 40 mph Ride level 1		Perryman 3 @ 10 mph Ride level 2		Churchville B @ 12 mph Ride level 3		Perryman 2 @ 23 mph Ride level 4	
	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev	Ave	Std Dev
Vertical Position (inch)	0.44	0.00	1.78	0.00	2.16	0.00	2.21	0.01
Roll Position (deg)	0.52	0.00	0.25	0.00	0.23	0.00	0.91	0.00
Pitch Position (deg)	0.30	0.00	2.10	0.00	2.39	0.00	1.52	0.00
Yaw Position (deg)	4.49	0.01	0.01	0.00	0.01	0.00	5.43	0.01
Vertical Acceleration (g)	0.05	0.00	0.10	0.00	0.13	0.01	0.25	0.01
Longitudinal Acceleration(g)	0.02	0.00	0.03	0.01	0.04	0.01	0.04	0.00
Lateral Acceleration (g)	0.02	0.00	0.02	0.01	0.02	0.01	0.03	0.00
Roll Rate (deg/sec)	2.79	0.02	1.42	0.05	1.47	0.04	4.68	0.03
Pitch Rate (deg/sec)	1.24	0.01	7.10	0.02	10.36	0.04	6.86	0.03
Yaw Rate (deg/sec)	1.15	0.01	0.35	0.01	0.50	0.01	1.48	0.01

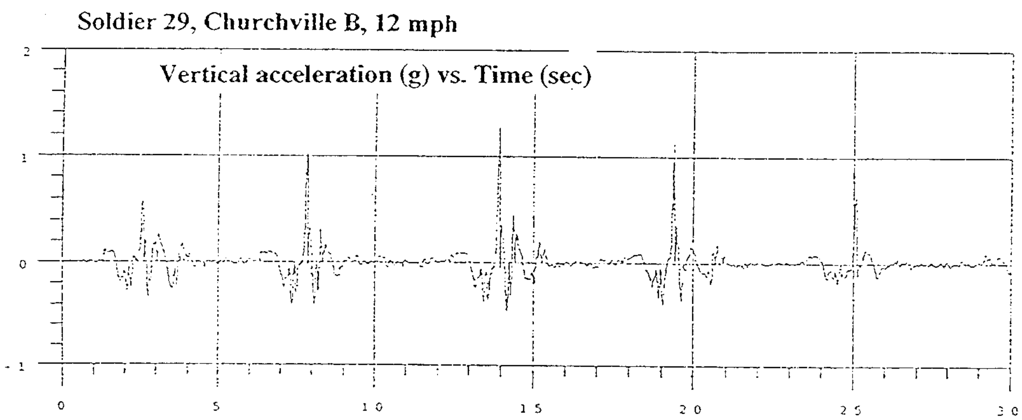
By observing the values in Tables 6 - 8, it can be concluded that the motion base produced the intended displacements, rates, and accelerations of each ride level with remarkable repeatability and probability. Another indication that the motion response was repeatable can be observed in Figure 8. Plotted are simulator vertical acceleration and pitch rate response verses a 30 second time period for soldiers 21 and 29 while traversing the Churchville B simulation. Note that nearly identical acceleration and pitch rate was experienced by two soldiers although they were tested on different days. The high-amplitude transients represent the M1 vehicle dynamic response while traversing over the large speed bumps inherent in the Churchville B terrain. These plots are typical of the nearly identical repeatability throughout the 4 weeks of the experiment. Additional selected plots of interest can be found in Appendix A titled "Data Acquisition" section of this report.

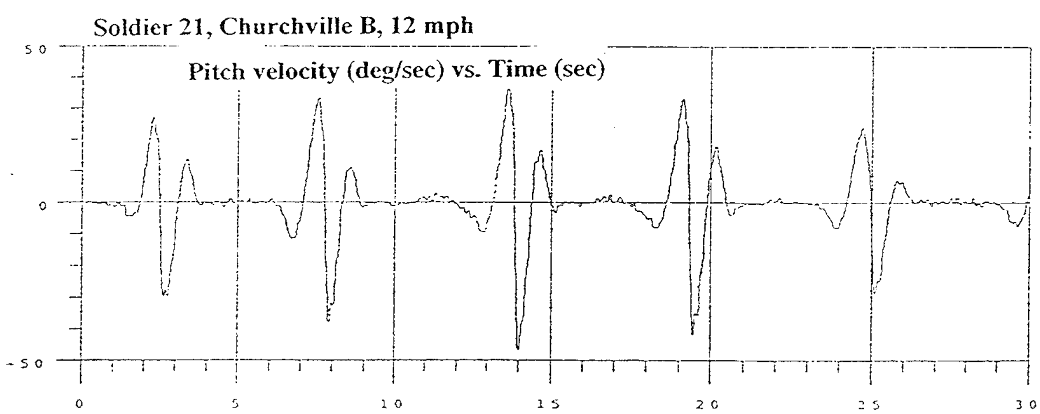
5.5.3 Slewing

Target slewing results were requested for all test runs. This analysis focuses on reporting 3 motion variables;

a) Absorbed power
b) Amplitude
c) Frequency.







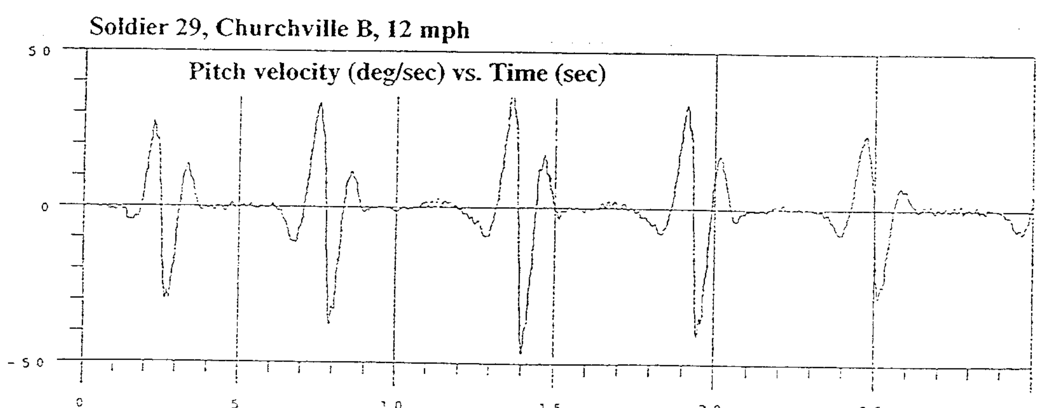


FIGURE 8. TIME PLOTS SHOWING REPEATABILITY

The definitions of these variables as they pertain to slewing are as follows;

a) Absorbed Power. Averaged vertical absorbed power computed from time of target presentation to trigger pull. The engineering units are watts.

b) Amplitude. Root-mean-squared (rms) of the vertical acceleration of the simulator seat bottom frame computed from time of target presentation to trigger pull. The engineering units are g's rms.

c) Frequency. The frequency value of the component that contains the greatest power spectrum value of vertical acceleration computed from time of target presentation to trigger pull. The engineering units are hertz.

5.5.4 Tracking

Target tracking results were requested for all test runs. As in the slewing tasks, the requirement was to provide 3 variables;

a) Absorbed power
b) Amplitude
c) Frequency.

The definitions of these variables as they pertain to tracking are as follows;

a) Absorbed Power. Averaged vertical absorbed power computed from time of target presentation to the last trigger pull for each target. The engineering units are watts.

b) Amplitude. Root-mean-squared (rms) of the vertical acceleration of the seat bottom frame computed from time of target presentation to the last trigger pull for each target. The engineering units are g's rms.

c) Frequency. The frequency value of the component that contains the greatest power spectrum value in the vertical acceleration data computed from time of target presentation to the last trigger pull for each target. The engineering units are hertz.

The three variables are reported once for each target presentation for a typical 1 minute tracking task.

5.5.5 Software and Results

The motion variable entries of absorbed power, amplitude and frequency for the slewing and tracking data are the results of running the software program "ANALYZE." ANALYZE was written by the Physical Simulation Team of TARDEC specifically for the Controller experiment. ANALYZE reads, as input, the raw motion and discrete data defined in the data acquisition section. It then computes the three desired variables based on target and soldier trigger pull events.

There are some cases where data anomalies occur in the slewing tasks. The "Absorbed Power" and "Frequency" values are computed using frequency-based functions such as the Discrete Fourier Transform. These functions require considerable ensemble data to produce results - generally the larger the ensemble, the more representative the results. In this experiment, a minimum of 128 data samples, which corresponds to 1.28 seconds of data, was chosen to produce meaningful results. Thus, computations are not valid for data sets under 1.28 seconds in length and a "-1" entry is given to designate this. This would correspond to a soldier who pulled a trigger less than 1.28 seconds after a target appeared in the slewing tasks. For example, this is evident in soldier 12, iteration 2, ride level 2, at the 4th target.

Similarly, there are data anomalies in the tracking tasks. There are several data sets in which the trigger was not pulled during one or more targets. In these cases, a "-1" is entered to designated a "no data" case. For example, This is evident in soldier 12, iteration 1, ride level 4, at the 2nd target which was not fired upon.

In operation, the results of ANALYZE are stored in a VMS ASCII file on a TARDEC VAX computer. These files are used to create the spreadsheet format requirement of the test plan. The slewing and tracking spreadsheet results are recorded to an MS-DOS floppy disk. Note that no entries are given for the zero ride level, as since the simulator was stationary during zero ride level, motion data is not applicable (all values are zero).

There are 144 data entries per soldier for the slewing tasks. This corresponds to 3 variables*6 targets*4 rides*2 iterations = 144. There are 72 data entries per soldier for the tracking tasks. This corresponds to 3 variables*3 targets*4 rides*2 iterations = 72.

The process in which the test-required spreadsheet data was assembled is described in Figure 9. In step 1, simulator motion data is recorded and stored on a Digital Equipment Corporation VAX computer. Simultaneously, soldier performance data is recorded and housed in a Silicon Graphics Incorporated VGX computer. In step 2, analyses on these data are performed to determine the vibration and performance results per the test protocol requirements. In step 3, these analyses are compiled into new data files on the VAX and VGX computers respectively. In step 4, these new files are edited to create a single data file on a Personal Computer in an ASCII format per the test protocol.

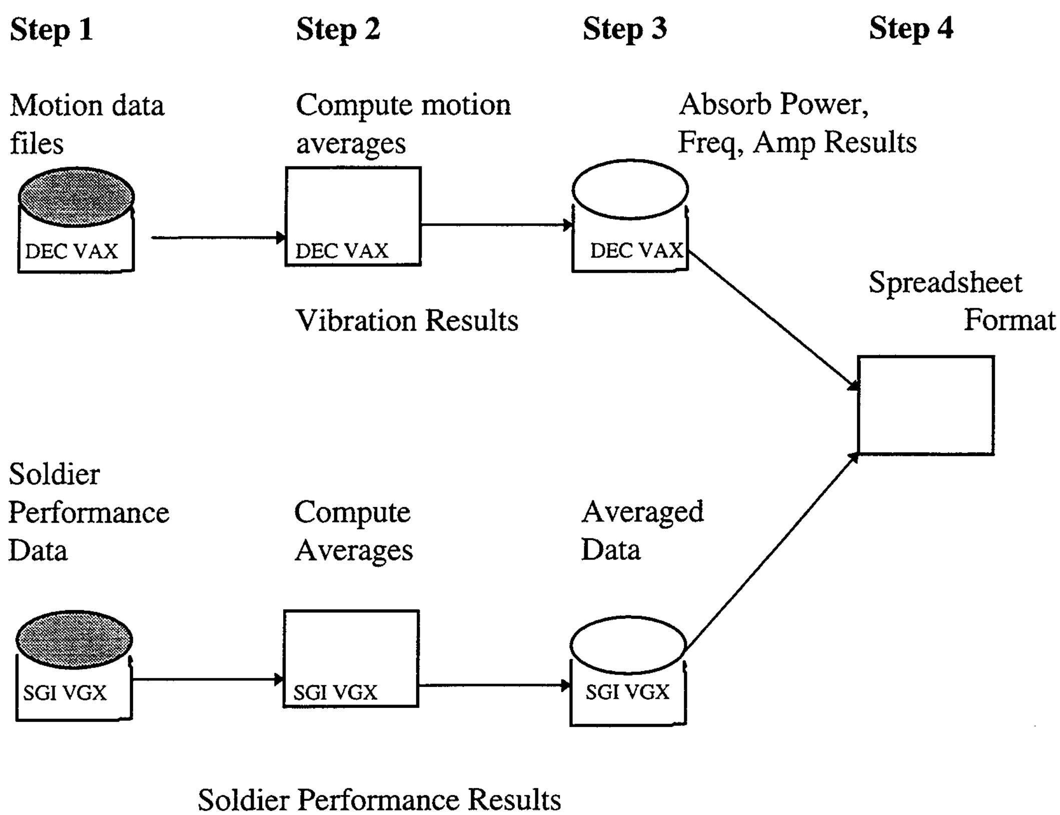


FIGURE 9. DATA ANALYSIS AND EDITING PROCESS

REFERENCES

1. R. A. Lee and F. Pradko, Analytical Analysis of Human Vibration (680091). Detroit, MI: Society of Automotive Engineers, 1968.

2. A. A. Reid, User's Manual for the RMS (TR - 13464). Warren, MI: U.S: Army Tank-automotive and Armaments Command, 1989.

3. Bosch Automotive Handbook, 3rd Edition, 1993.

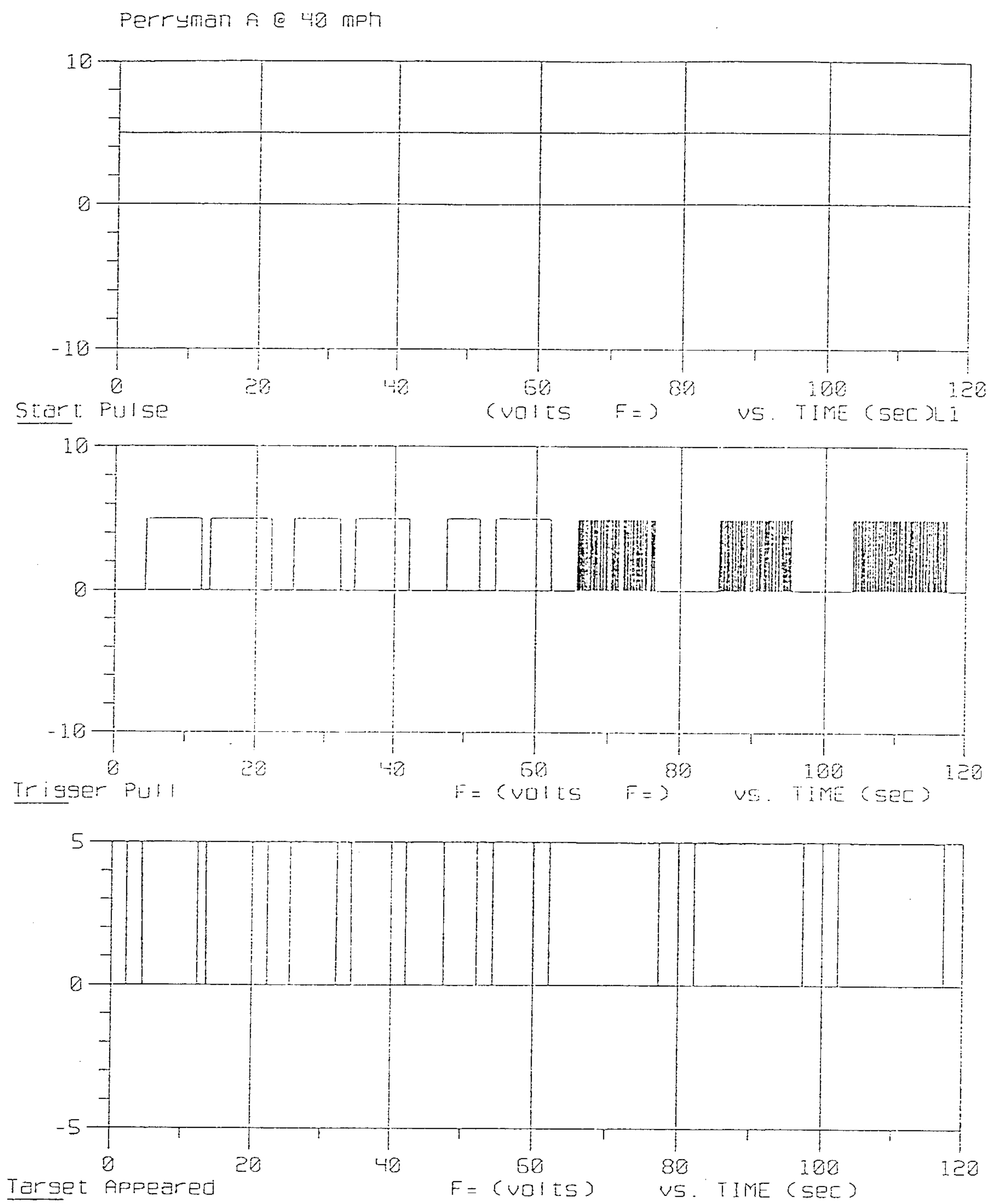
4. L. R. Rabiner, R. W. Schafer, and D. Dlugos, Periodogram Method for Power Spectrum Estimation, Programs for Digital Signal Processing, IEEE Digital Signal Processing Committee, 1979.

ACRONYMS

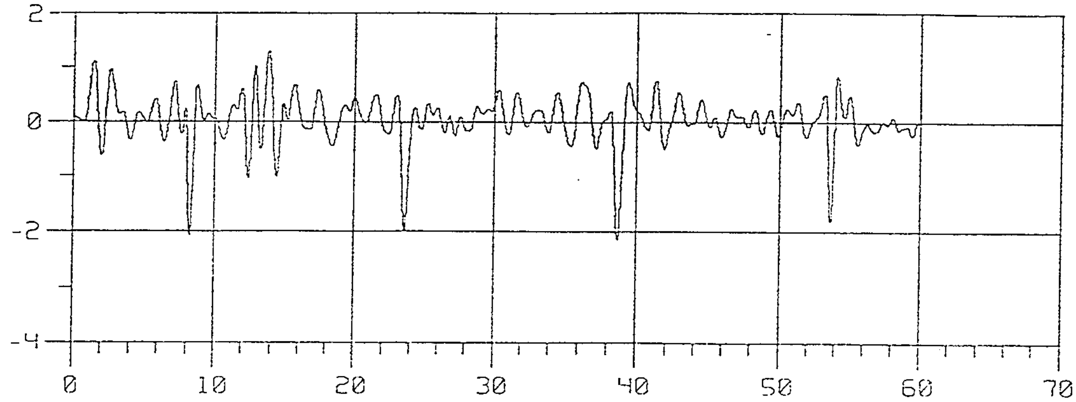
APG	Aberdeen Proving Grounds
ARL	Army Research Laboratory
ATD	Advanced Technology Demonstrator
ADC	Analog to Digital Converter
CA ATD	Crewman's Associate Advanced Technology Demonstrator
CAMAC	Computer Automated Measurement and Control
DAC	Digital to Analog Converter
DADS	Dynamic Analysis Design Software
DCD	Director of Combat Development
DOF	Degree of Freedom
FMBT	Future Main Battle Tank
HRED	Human Research and Engineering Directorate
HUC	Human Use Committee
KSC	Kinetic Systems Corporation
LCD	Liquid Crystal Display
MOS	Military Occupational Specialty
OSHA	Occupational Safety Health Agency
POI	Point of Interest
PSL	Physical Simulation Laboratory
RDTE	Research, Development, and Test Evaluation
RMS	Ride Motion Simulator
rms	Root Mean Square
TACOM	Tank-automotive and Armaments Command
TARDEC	Tank Automotive Research, Development and Engineering Center
UPS	Uninterruptible Power Supply

APPENDIX A

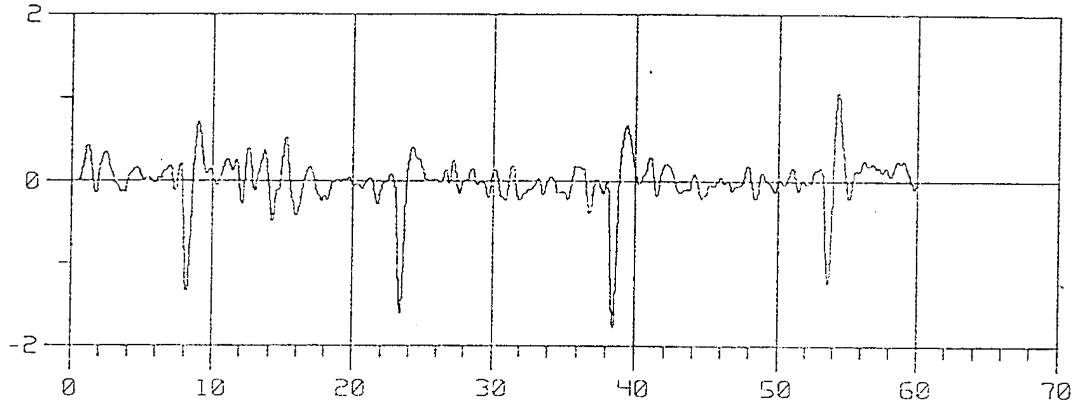
Data Acquisition


Perryman A @ 40 mph
10
0
-10
0
20
40
60
80
100
120
Start Pulse
(volts F=) vs. TIME (sec)L1
10
0
-10
0
20
40
60
80
100
120
Trigger Pull
F= (volts F=) vs. TIME (sec)
5
0
-5
0
20
40
60
80
100
120
Target Appeared
F= (volts) vs. TIME (sec)

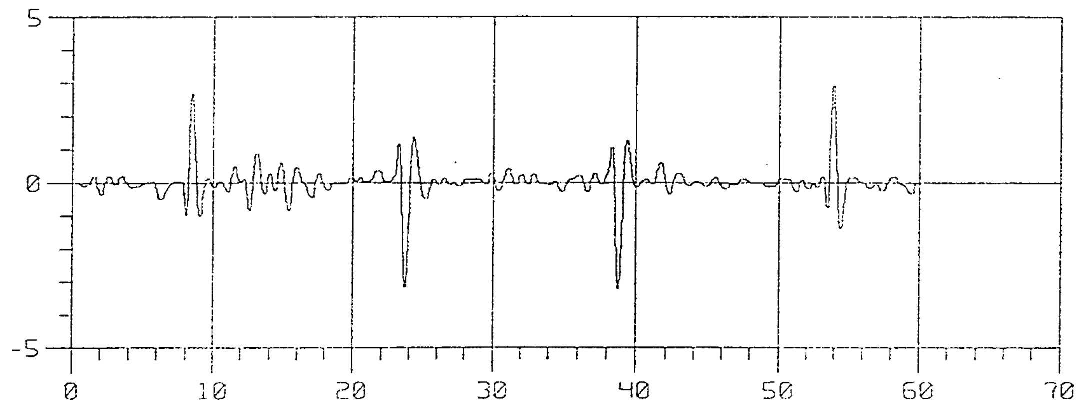
Perryman A @ 40 mph



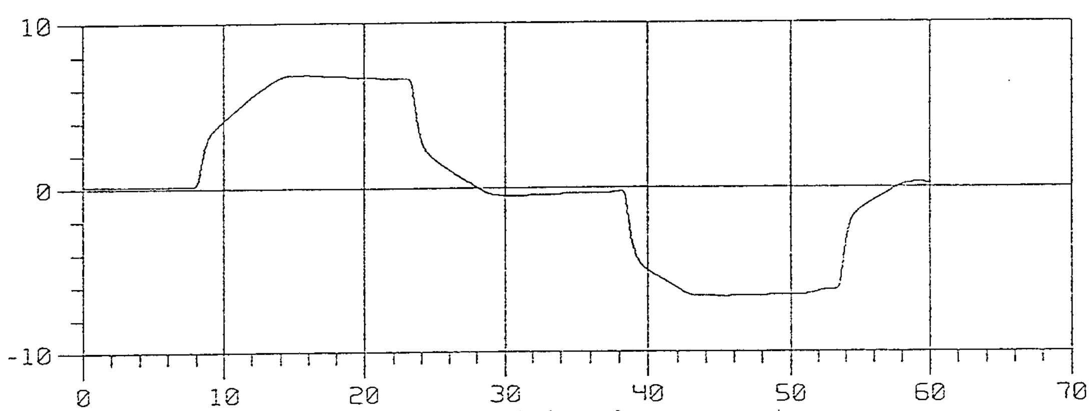
Vertical Displacement (inch) vs. TIME (sec)L1



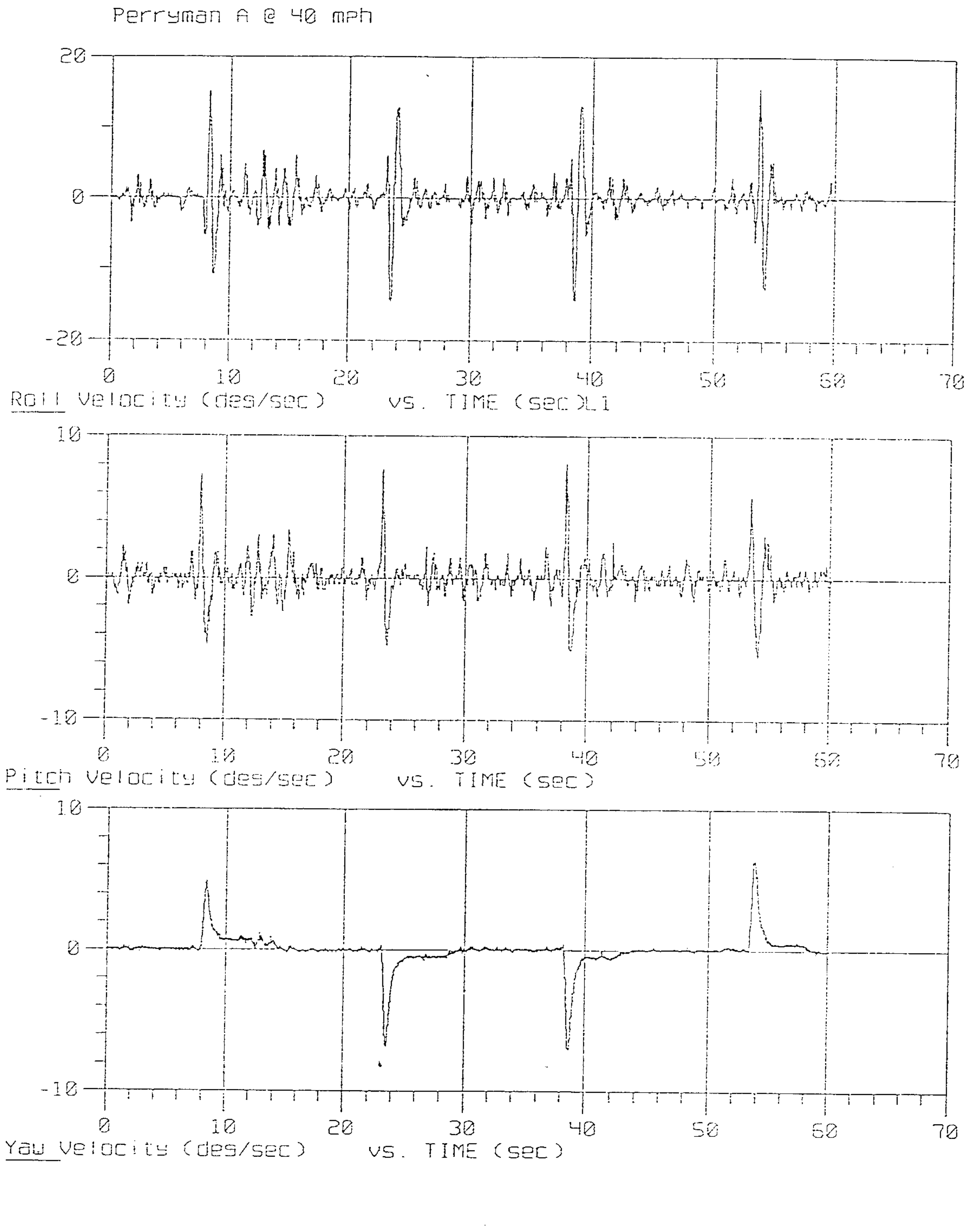
Pitch Displacement (deg) vs. TIME (sec)L1

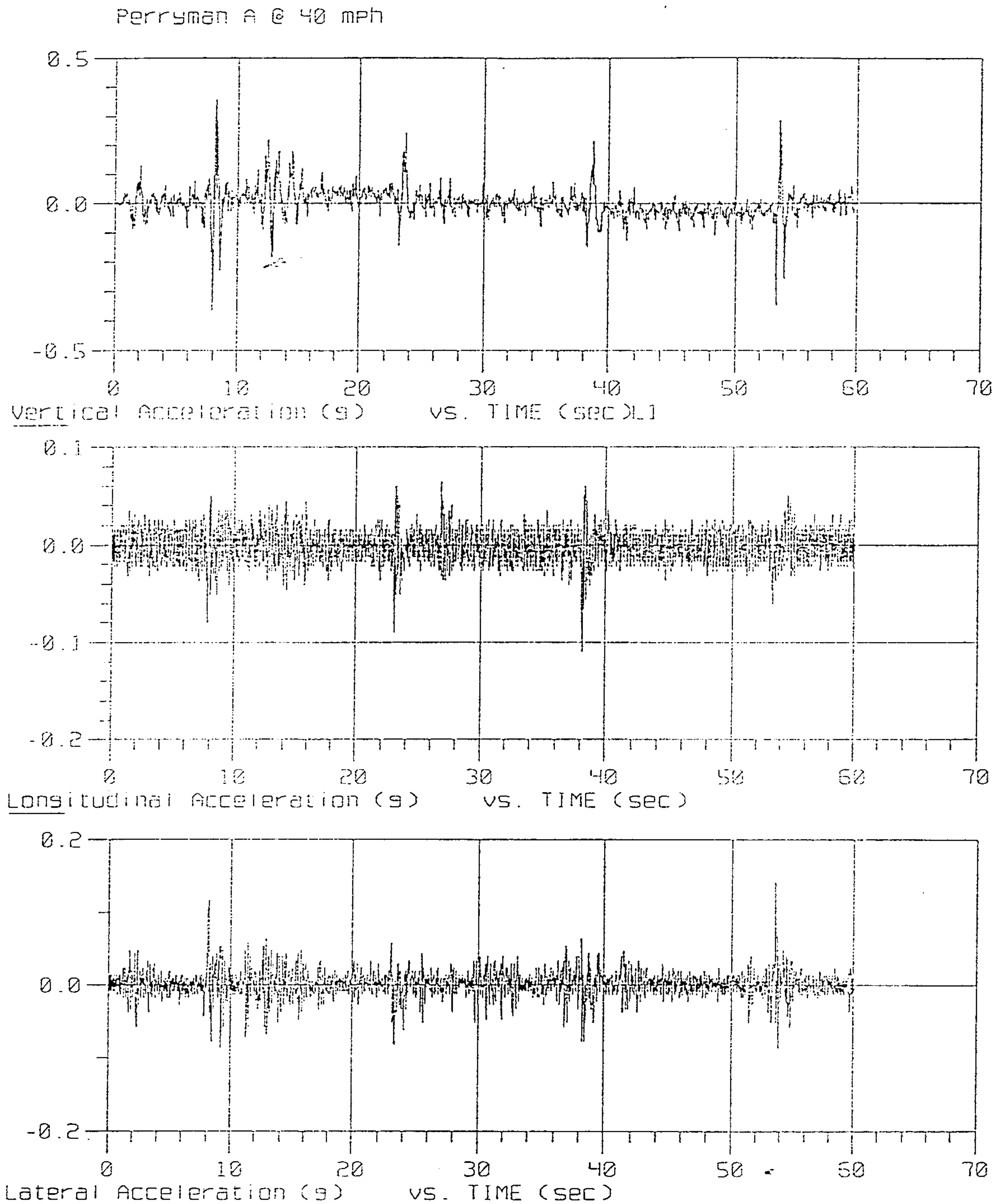


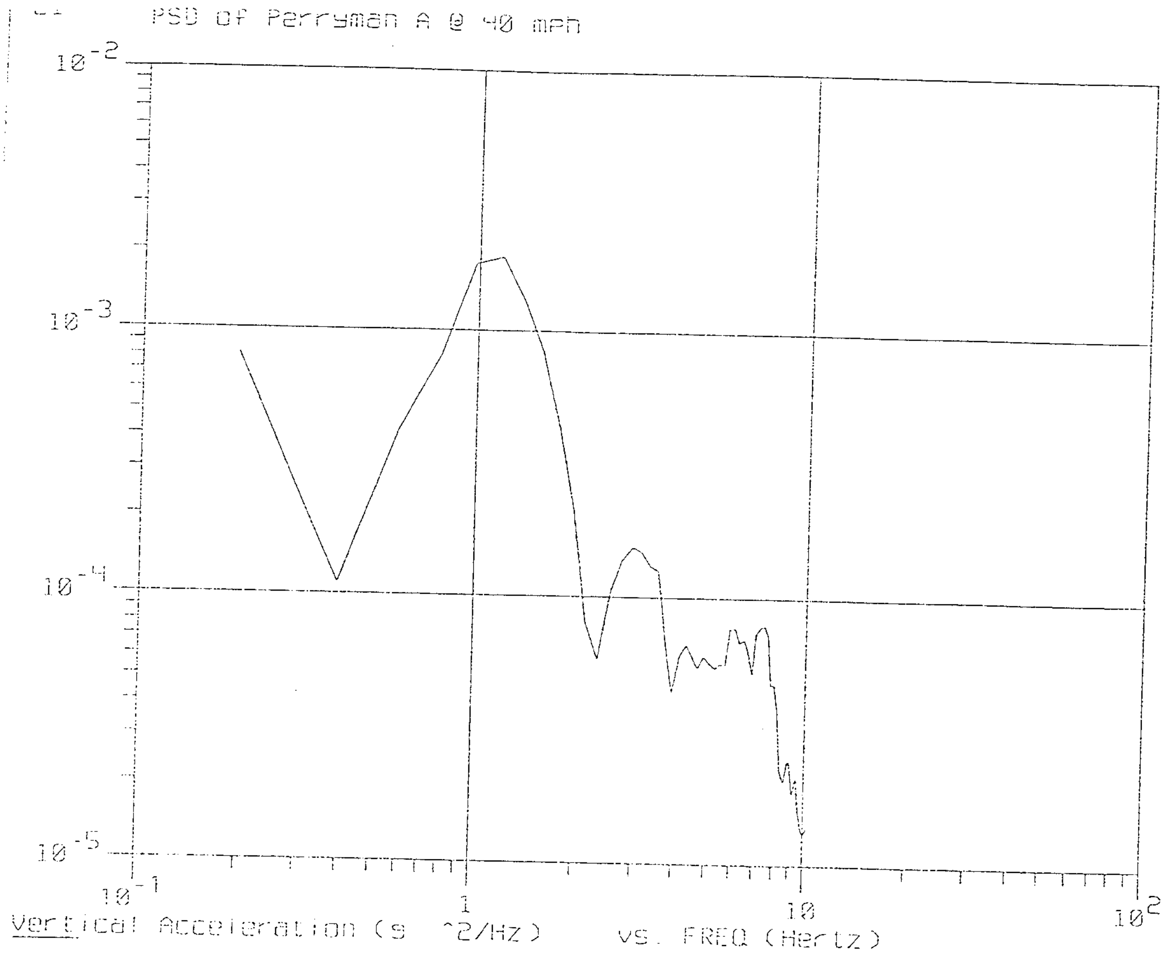
Roll Displacement (deg) vs. TIME (sec)

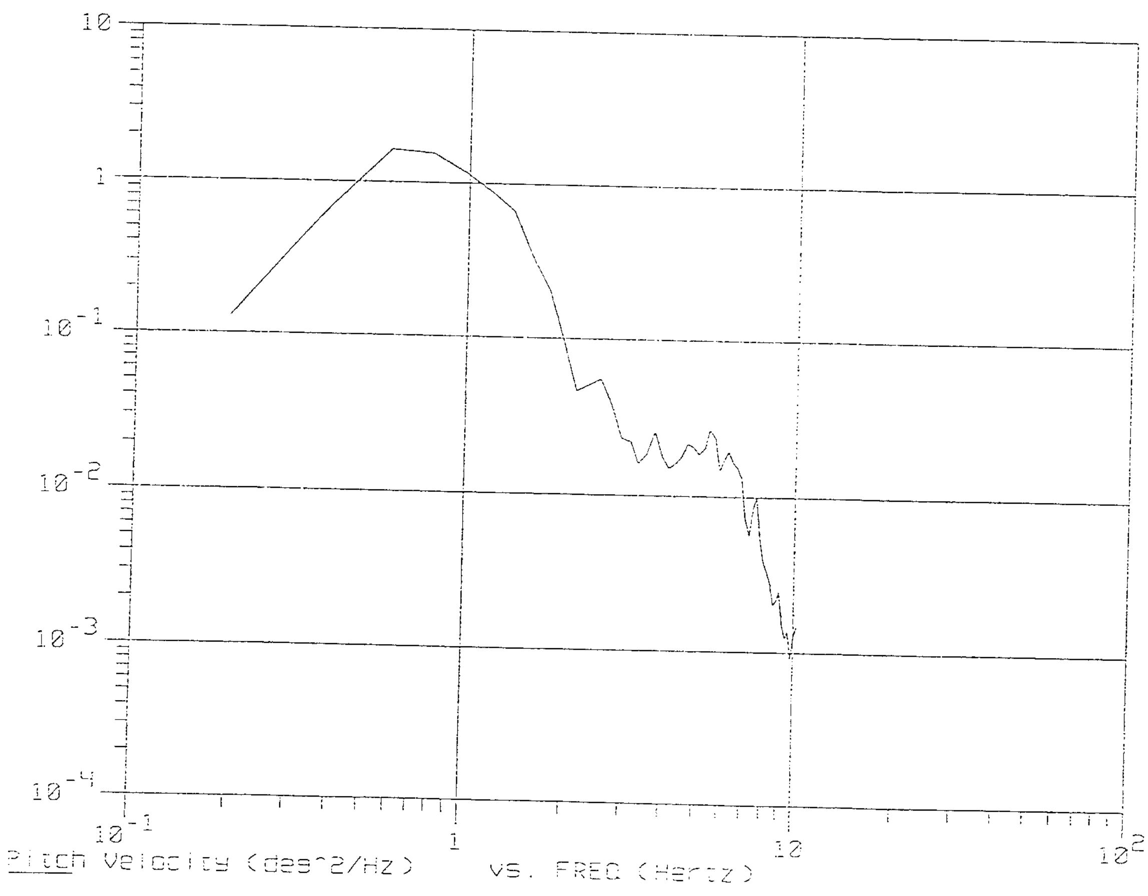


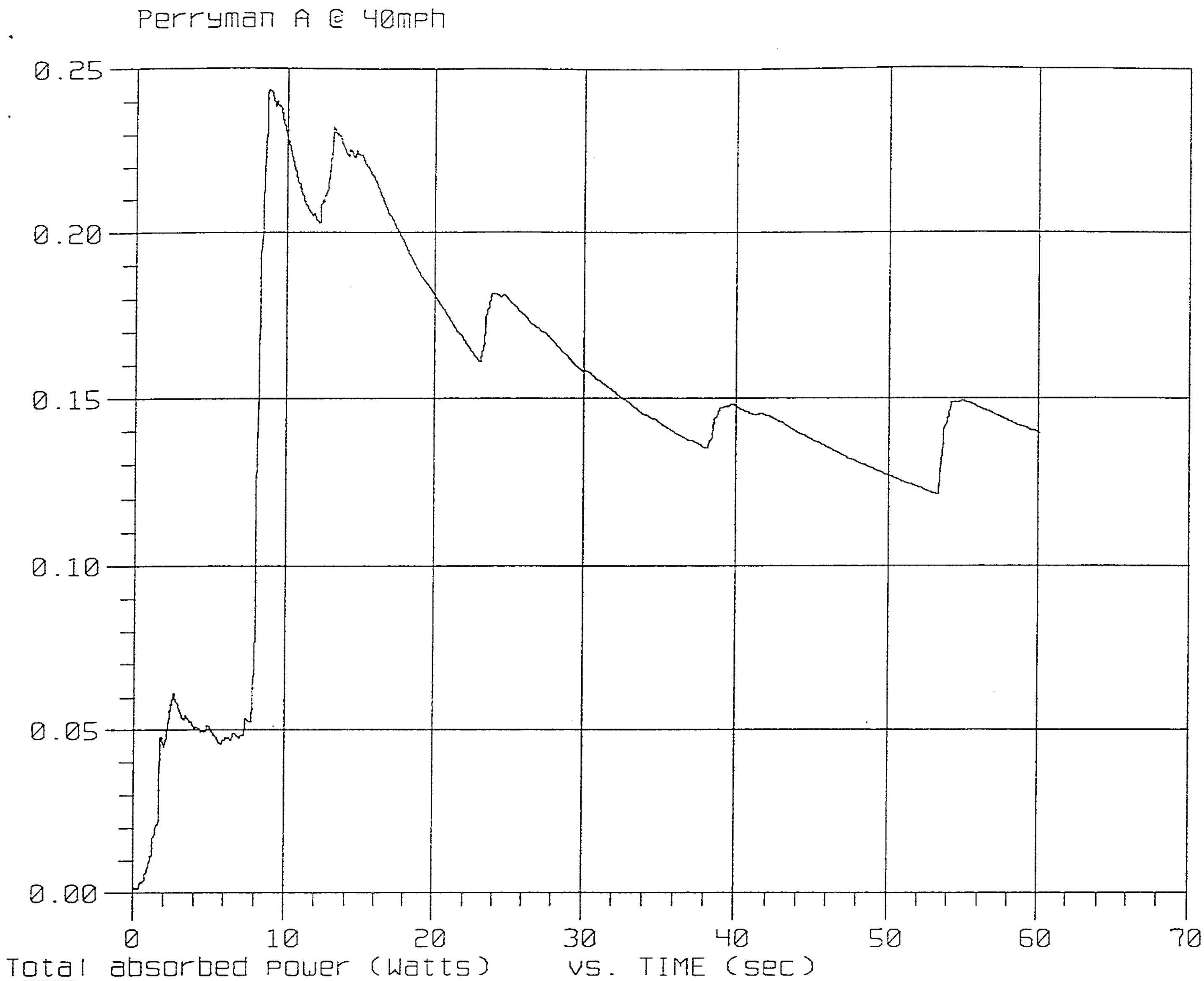
Yaw Displacement (deg) vs. TIME (sec)


Perryman A @ 40 mph
20
0
-20
0 10 20 30 40 50 60 70
Roll Velocity (deg/sec) vs. TIME (sec)
10
0
-10
0 10 20 30 40 50 60 70
Pitch Velocity (deg/sec) vs. TIME (sec)
10
0
-10
0 10 20 30 40 50 60 70
Yaw Velocity (deg/sec) vs. TIME (sec)

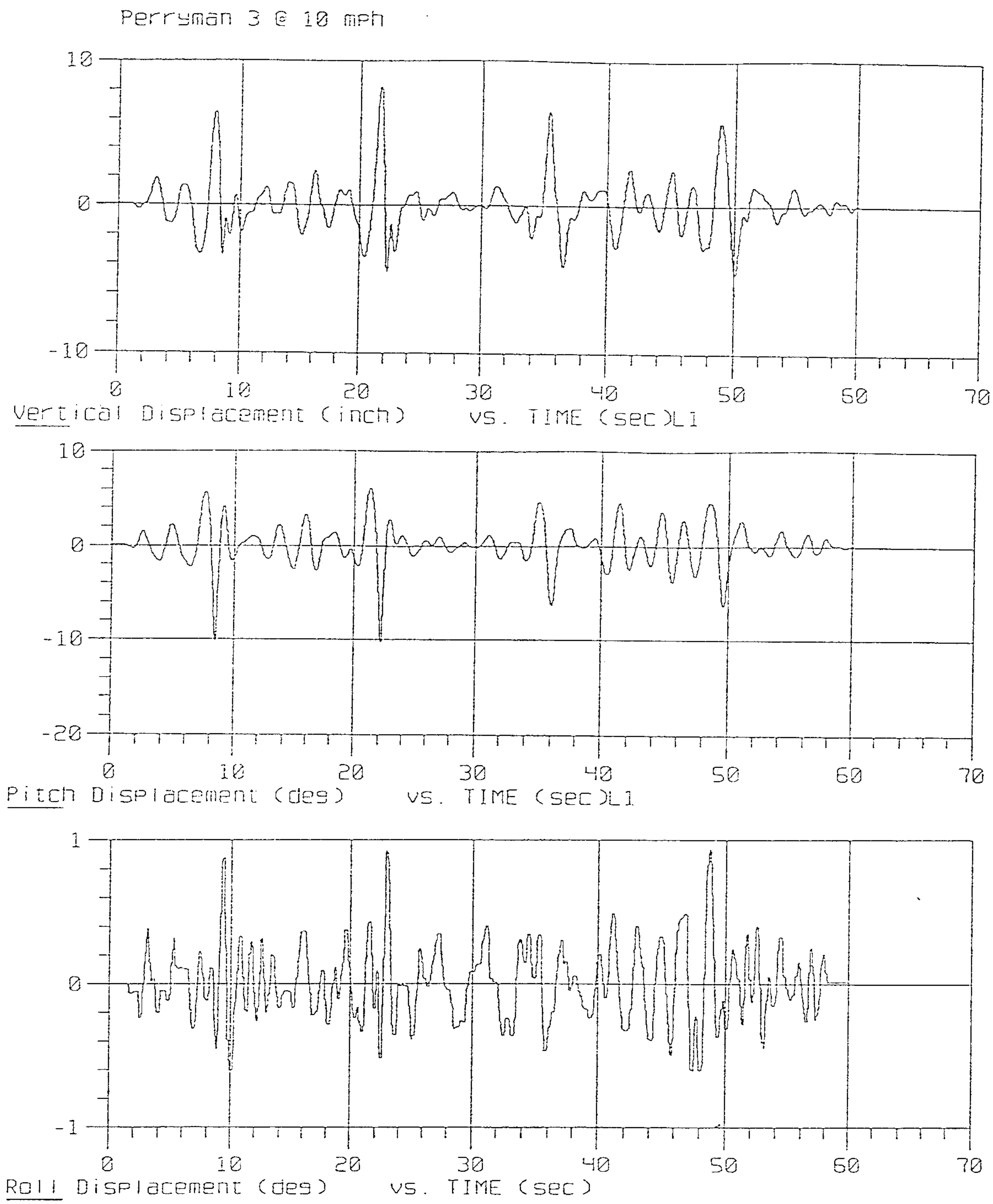

Perryman A @ 40 mph
0.5
0.0
-0.5
0
10
20
30
40
50
60
70
Vertical Acceleration (g) vs. TIME (sec)
0.1
0.0
-0.1
-0.2
0
10
20
30
40
50
60
70
Longitudinal Acceleration (g) vs. TIME (sec)
0.2
0.0
-0.2
0
10
20
30
40
50
60
70
Lateral Acceleration (g) vs. TIME (sec)

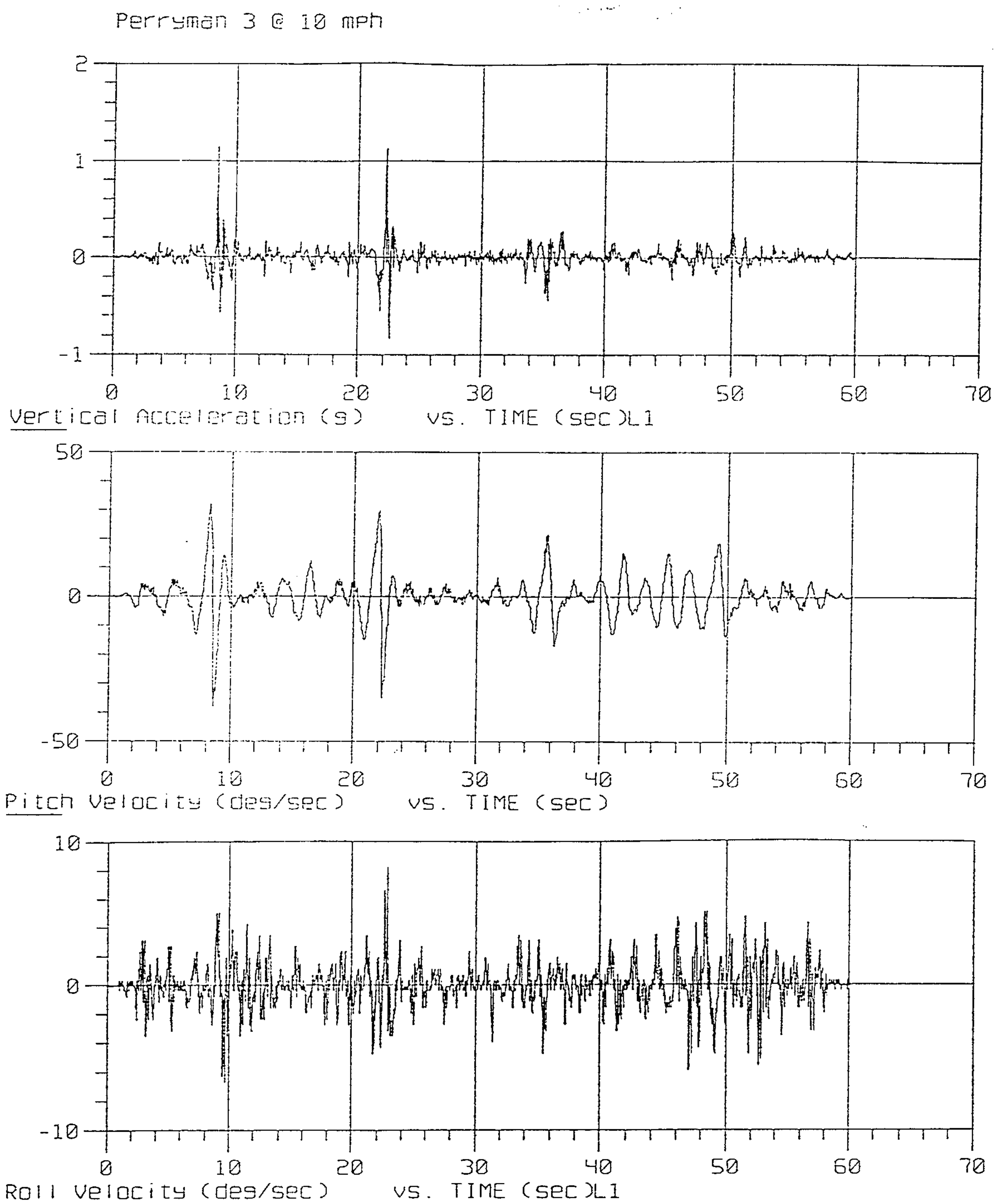

PSD of Perryman A @ 40 mph
10^-2
10^-3
10^-4
10^-5
10^-1
1
10
10^2
Vertical Acceleration (g^2/Hz) vs. FREQ (Hertz)


10
1
10^-1
10^-2
10^-3
10^-4
10^-1
1
10
10^2
Pitch Velocity (deg^2/Hz) vs. FREQ (Hertz)



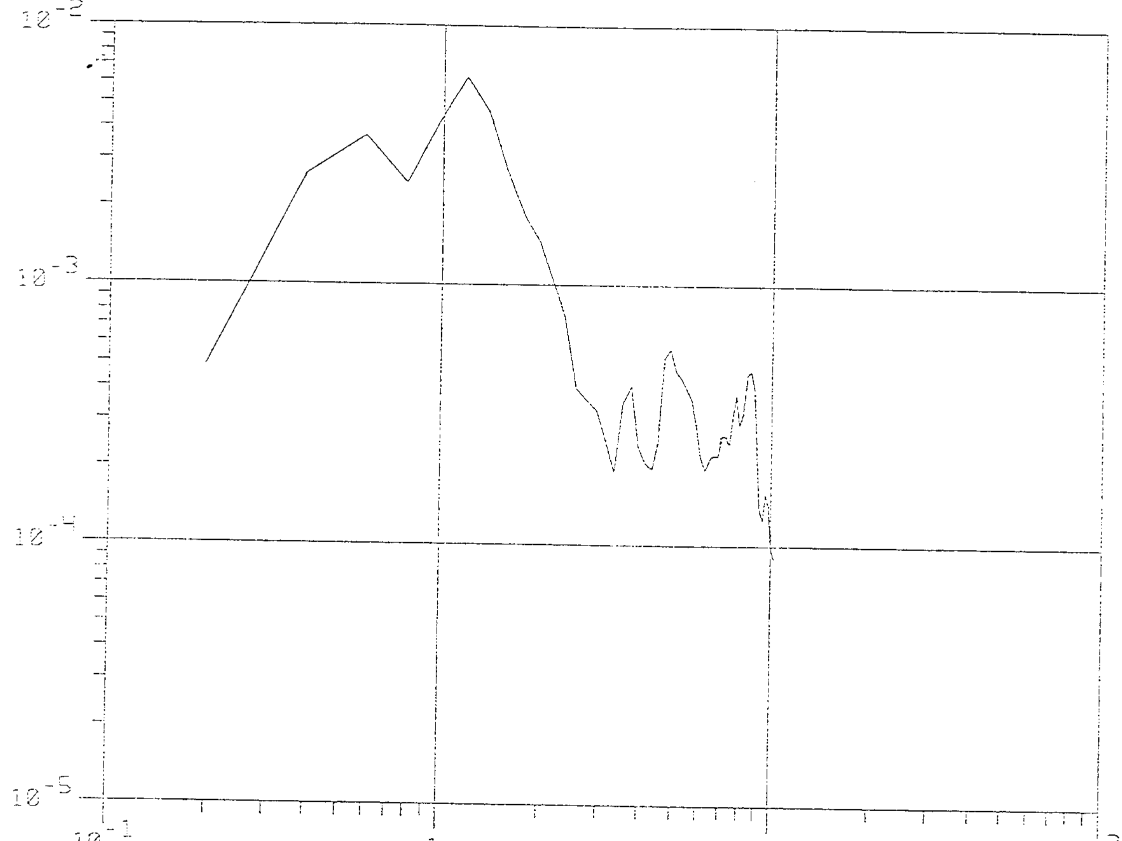
Perryman A @ 40mph
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
Total absorbed power (Watts) vs. TIME (sec)


Perryman 3 @ 10 mph
10
0
-10
0
10
20
30
40
50
60
70
Vertical Displacement (inch) vs. TIME (sec)L1
10
0
-10
-20
0
10
20
30
40
50
60
70
Pitch Displacement (deg) vs. TIME (sec)L1
1
0
-1
0
10
20
30
40
50
60
70
Roll Displacement (deg) vs. TIME (sec)

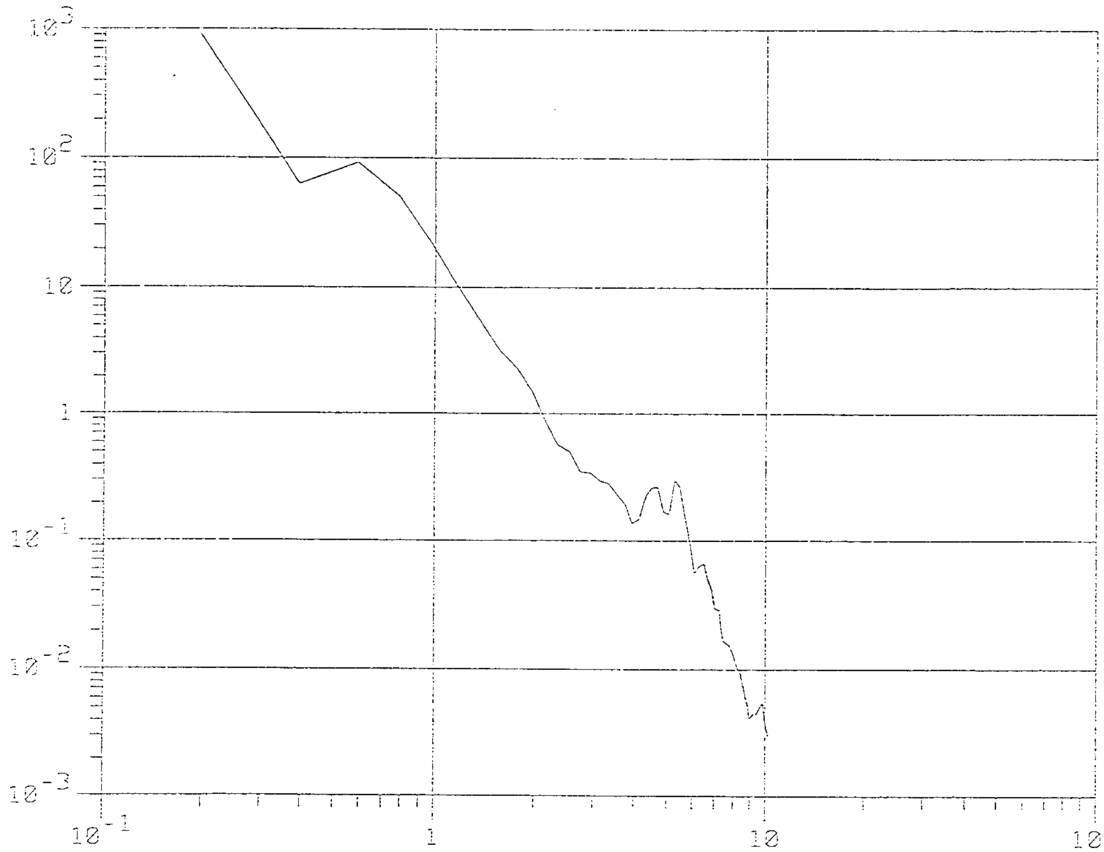


Perryman 3 @ 10 mph
Vertical Acceleration (g) vs. TIME (sec)L1
Pitch Velocity (deg/sec) vs. TIME (sec)
Roll Velocity (deg/sec) vs. TIME (sec)L1

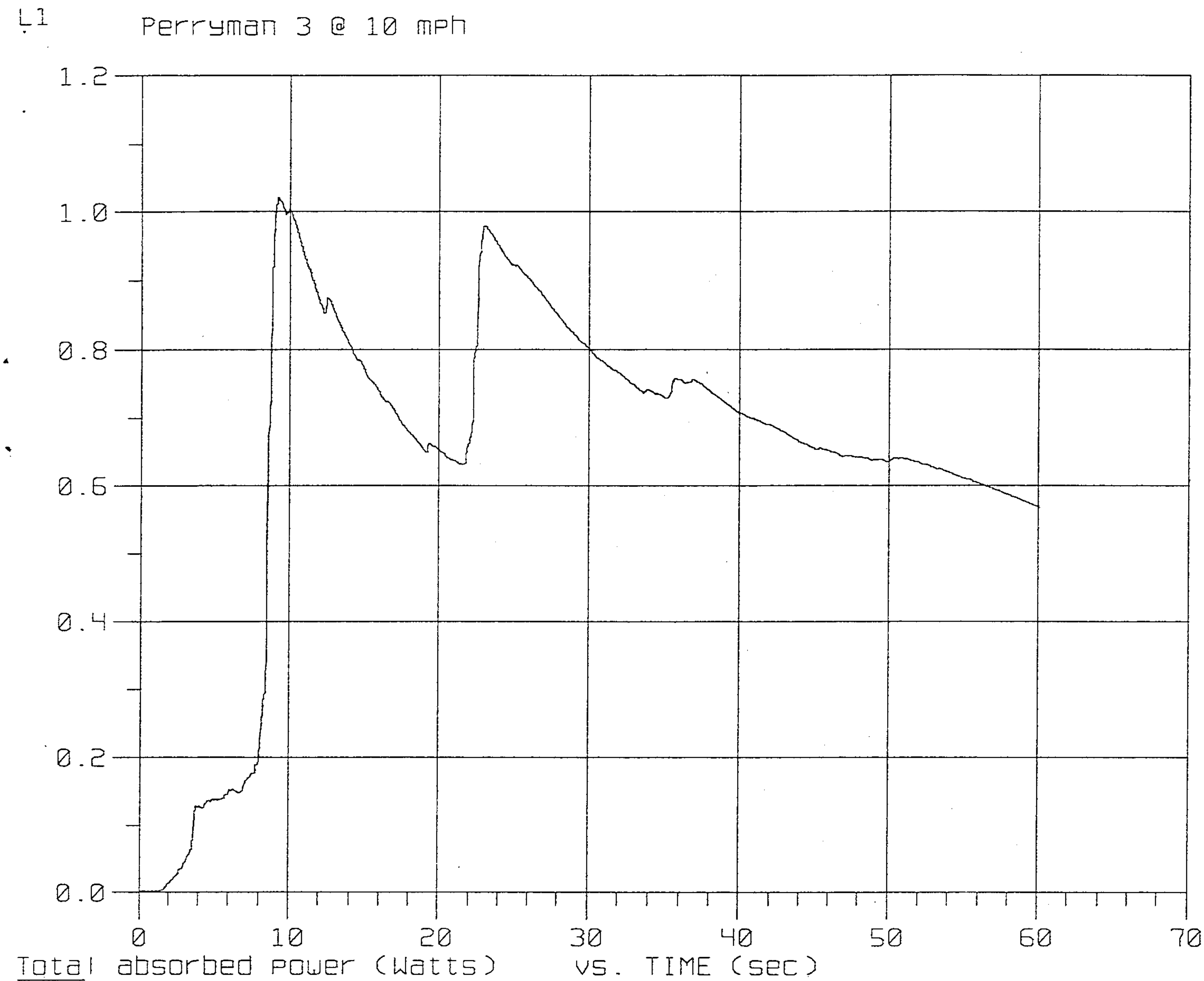
PSD of Perryman 3 @ 10 mph

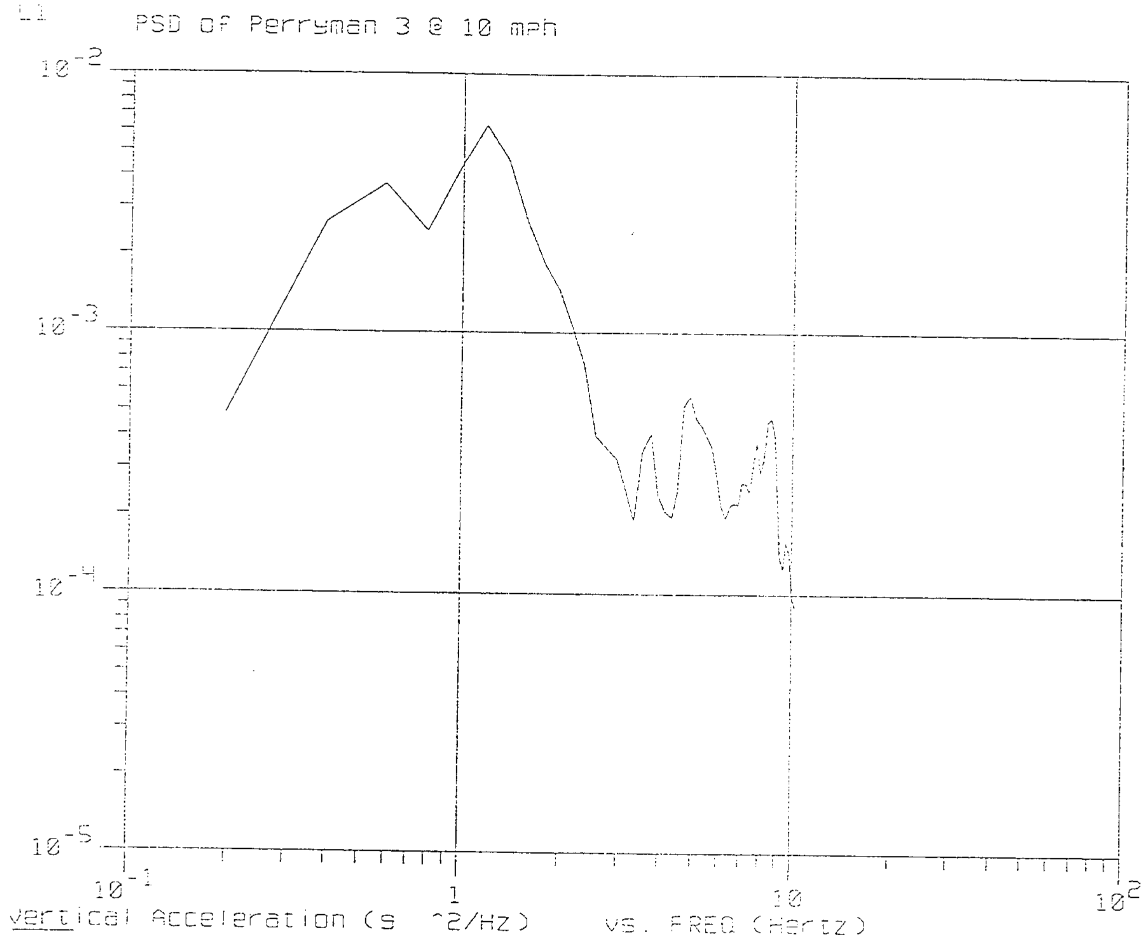


Vertical Acceleration (g ^2/Hz) vs. FREQ (Hertz)

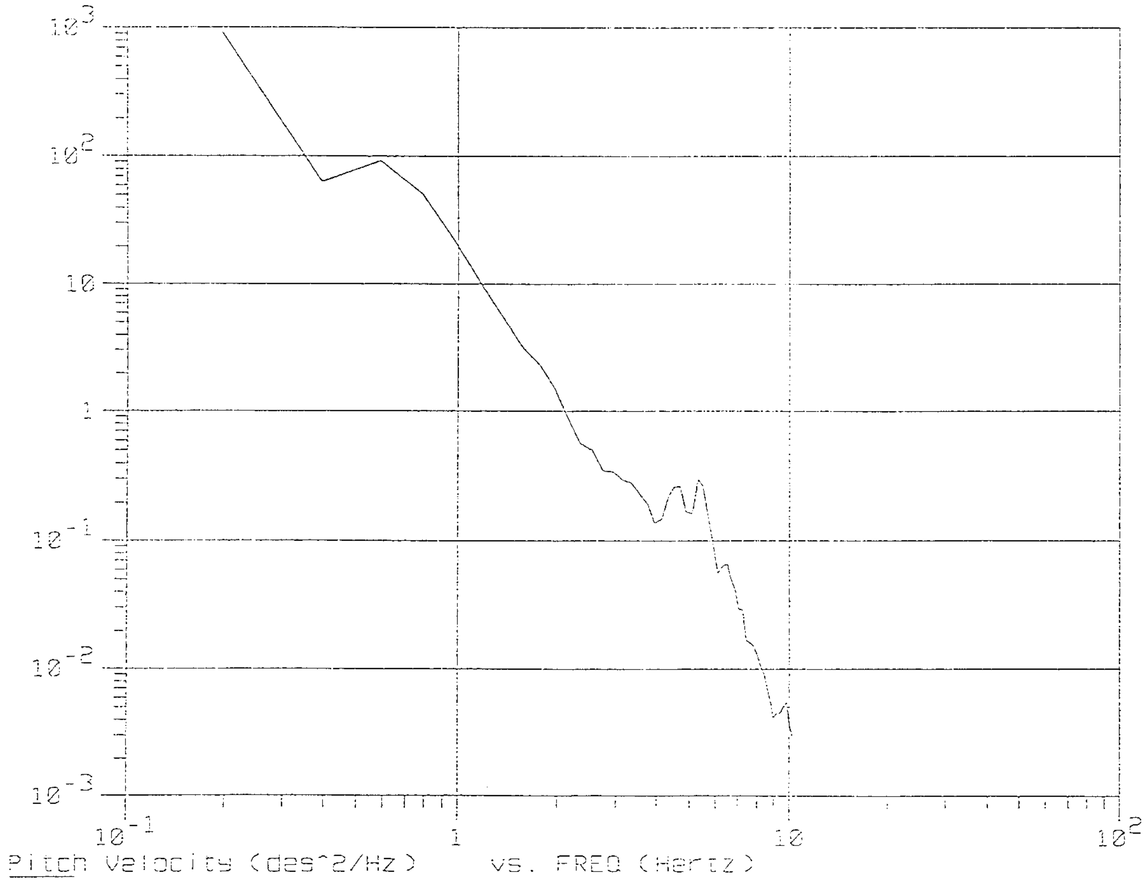


Pitch Velocity (deg^2/Hz) vs. FREQ (Hertz)


L1
Perryman 3 @ 10 mph
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
Total absorbed power (Watts) vs. TIME (sec)

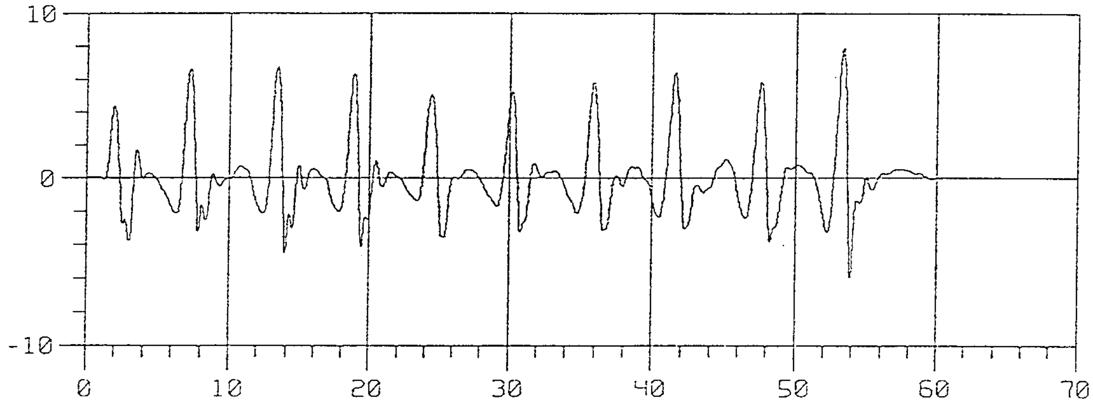


PSD of Perryman 3 @ 10 mph
10^-2
10^-3
10^-4
10^-5
10^-1
1
10
10^2
vertical Acceleration (g ^2/Hz) vs. FREQ (Hertz)

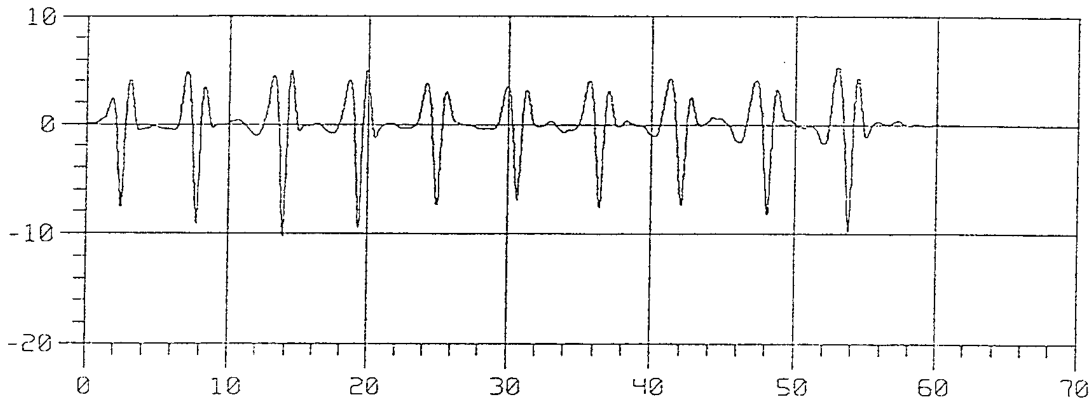


10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-1
1
10
10^2
Pitch Velocity (deg^2/Hz) vs. FREQ (Hertz)

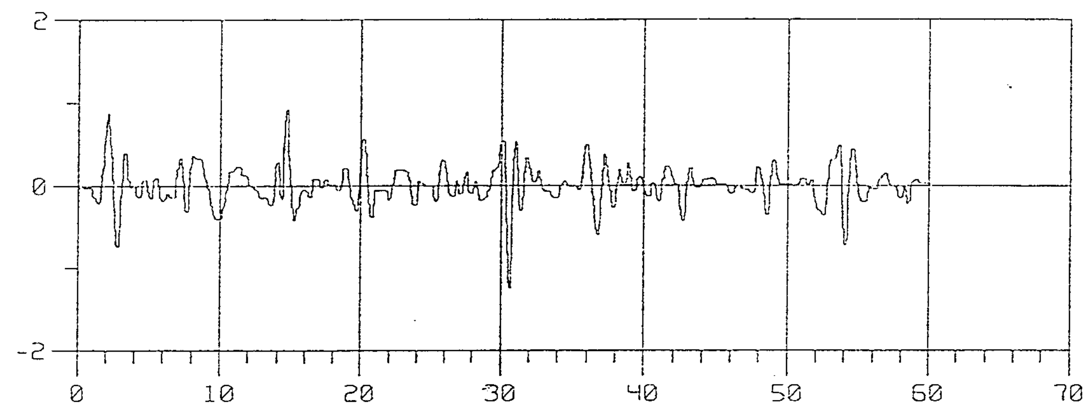
Churchville B @ 12 mph



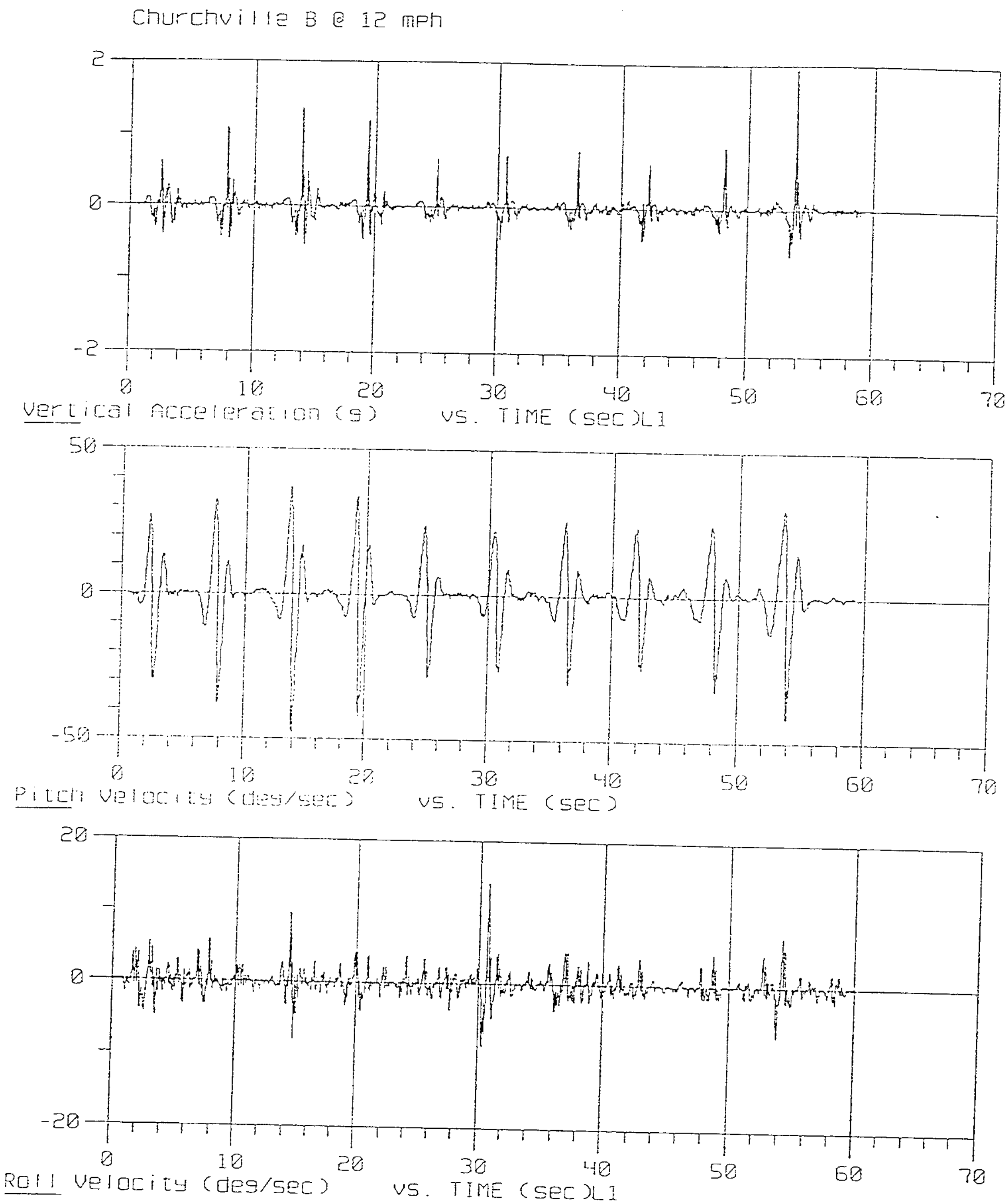
Vertical Displacement (inch) vs. TIME (sec)L1

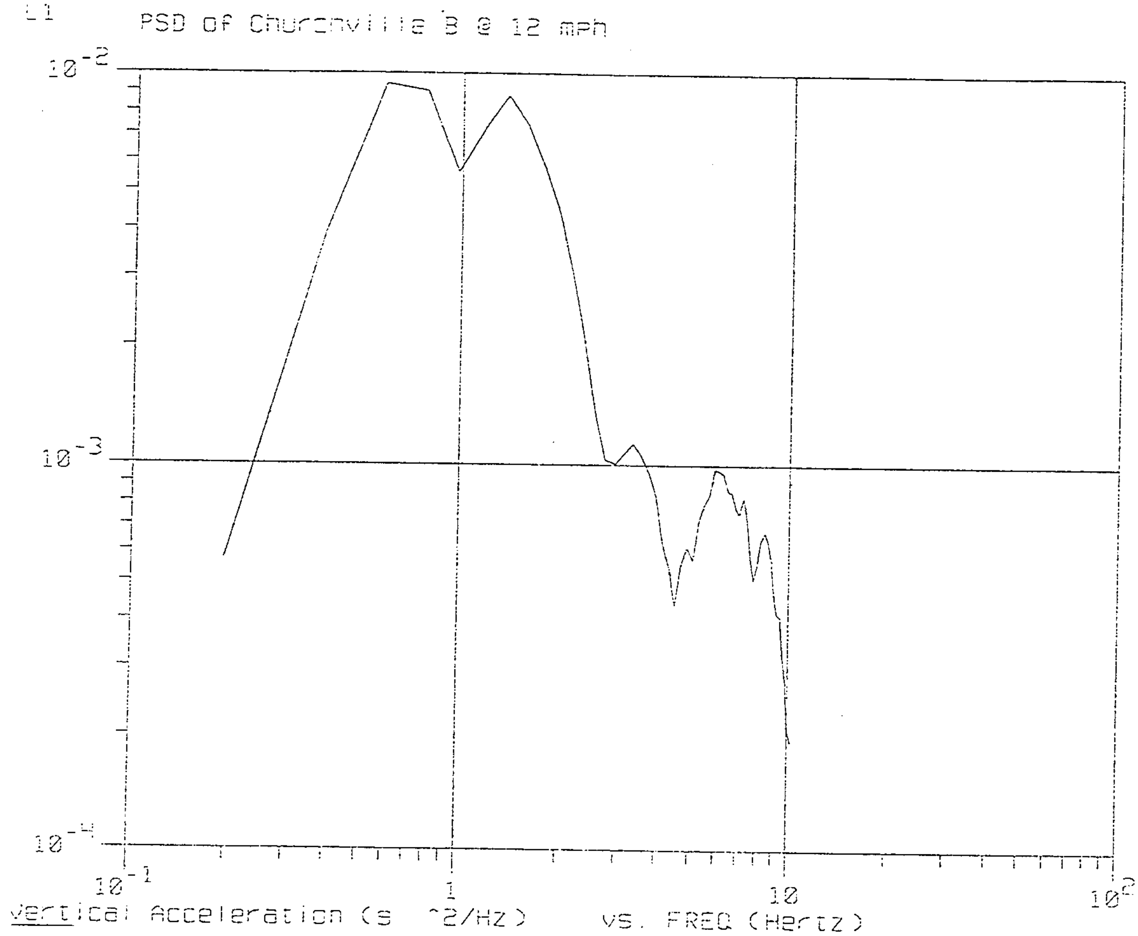


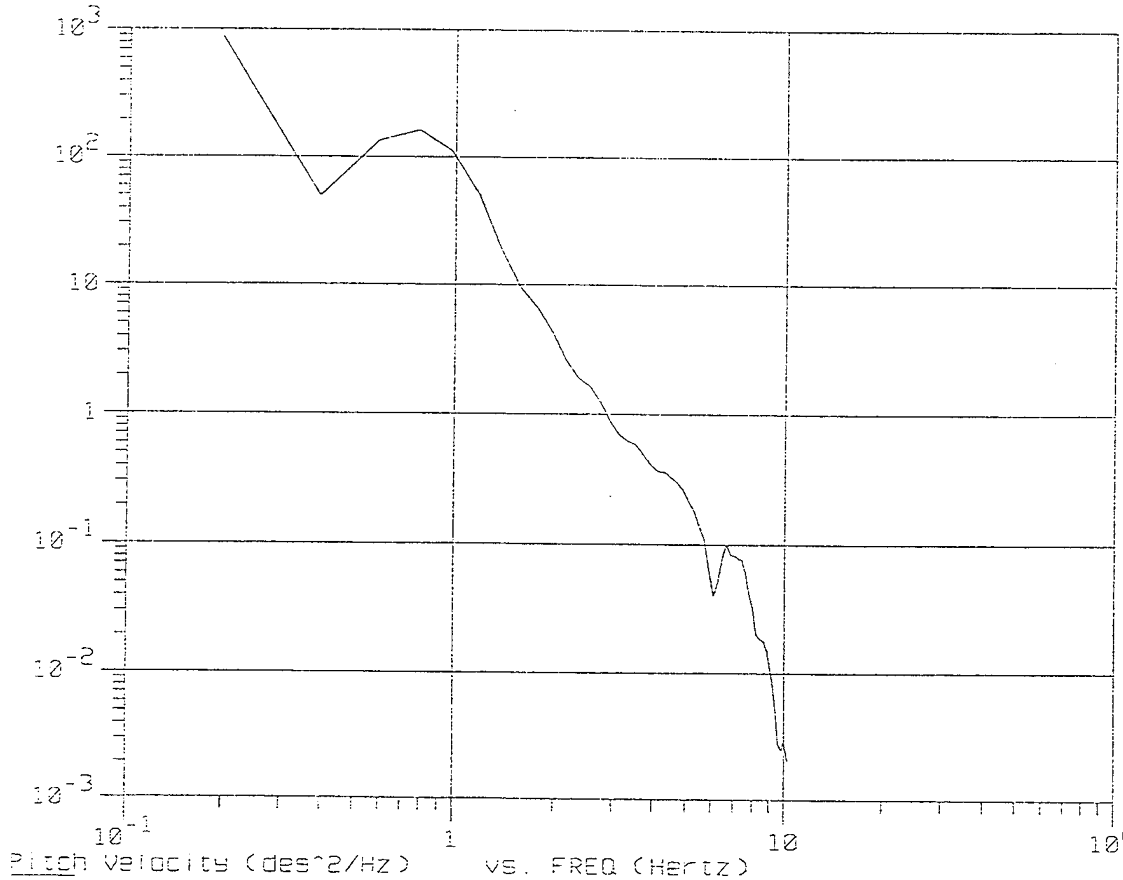
Pitch Displacement (deg) vs. TIME (sec)L1

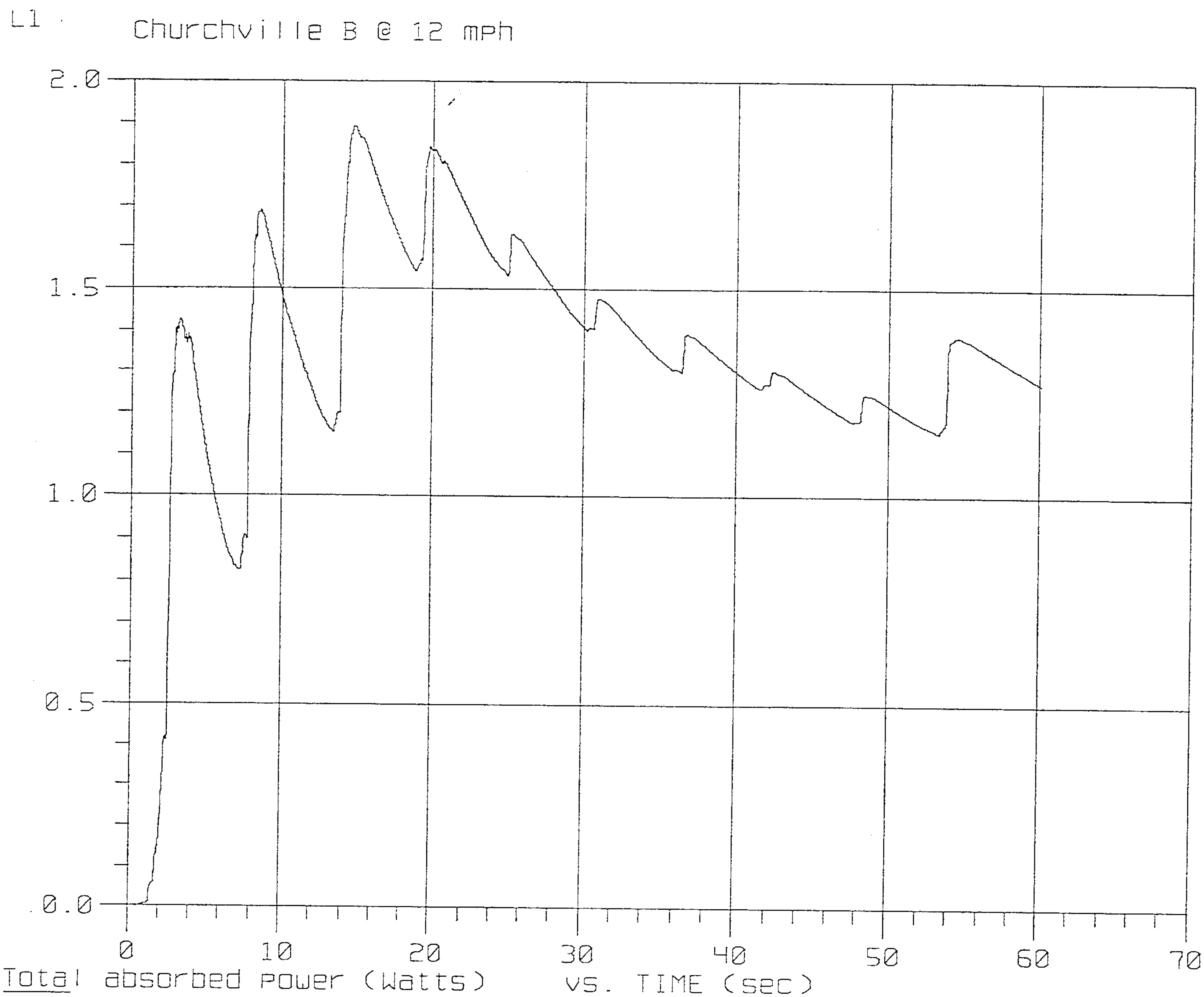


Roll Displacement (deg) vs. TIME (sec)


Churchville B @ 12 mph
2
0
-2
0
10
20
30
40
50
60
70
Vertical Acceleration (g) vs. TIME (sec)L1
50
0
-50
0
10
20
30
40
50
60
70
Pitch Velocity (deg/sec) vs. TIME (sec)
20
0
-20
0
10
20
30
40
50
60
70
Roll Velocity (deg/sec) vs. TIME (sec)L1

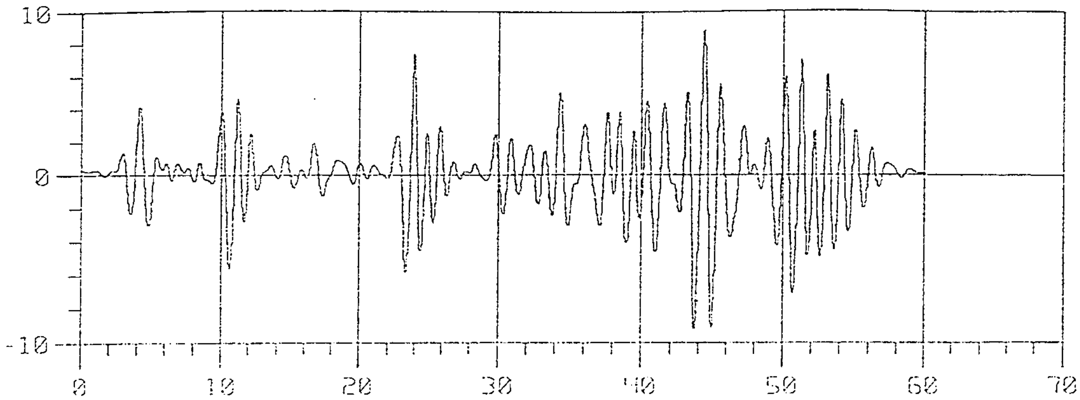

PSD of Churchville B @ 12 mph
10^{-2}
10^{-3}
10^{-4}
10^{-1}
1
10
10^{2}
Vertical Acceleration (g ^2/Hz) vs. FREQ (Hertz)


10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-1}
1
10
10^{2}
Pitch Velocity (deg^2/Hz) vs. FREQ (Hertz)

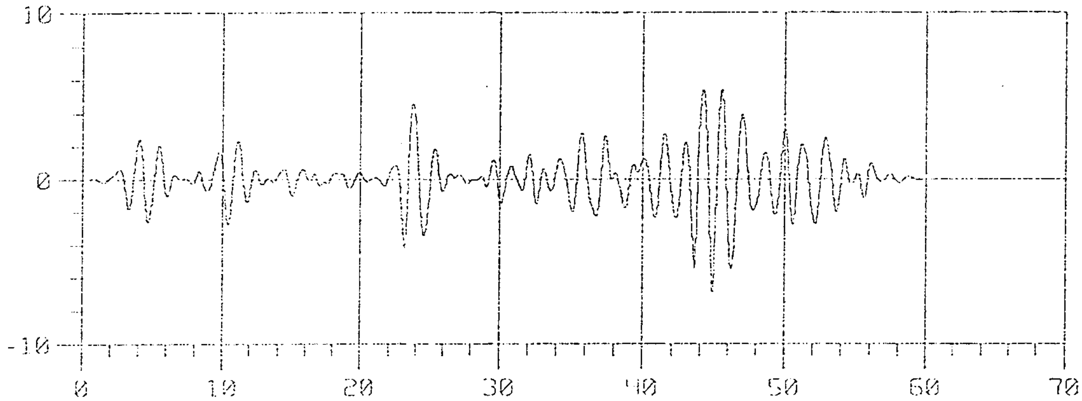


L1
Churchville B @ 12 mph
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Total absorbed power (Watts) vs. TIME (sec)

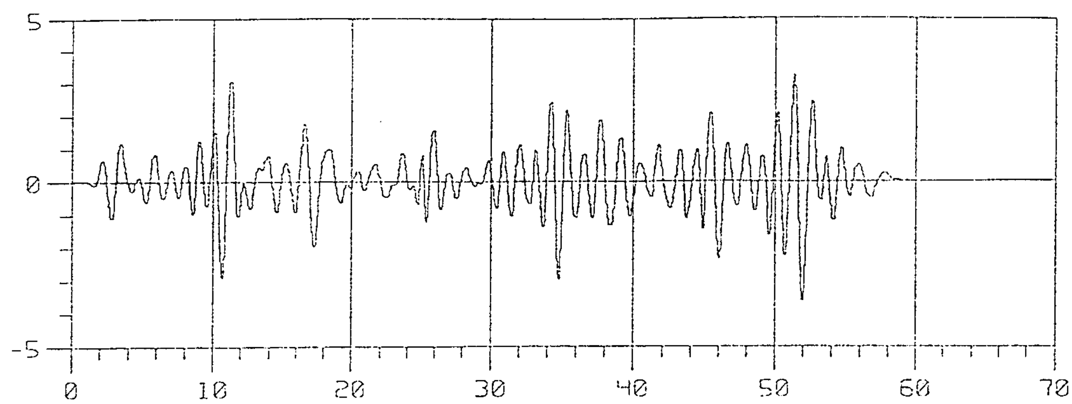
Perryman 2 @ 23 mph



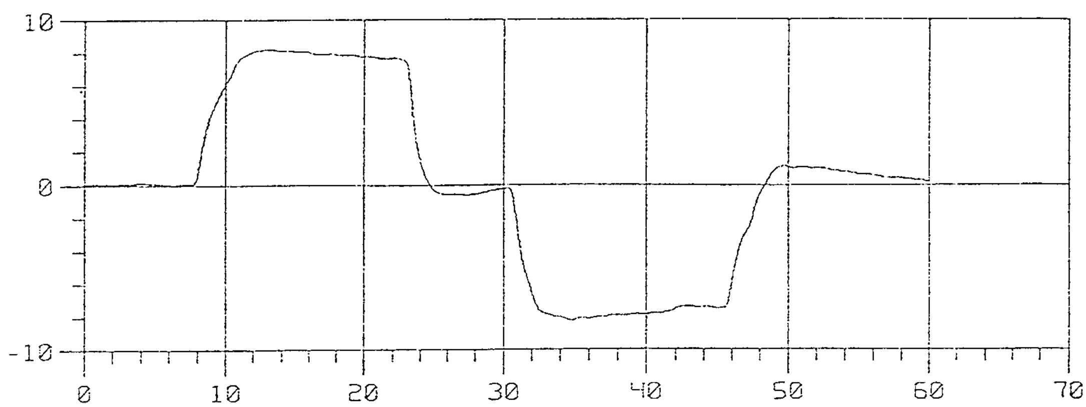
Vertical Displacement (inch) vs. TIME (sec)L1



Pitch Displacement (deg) vs. TIME (sec)

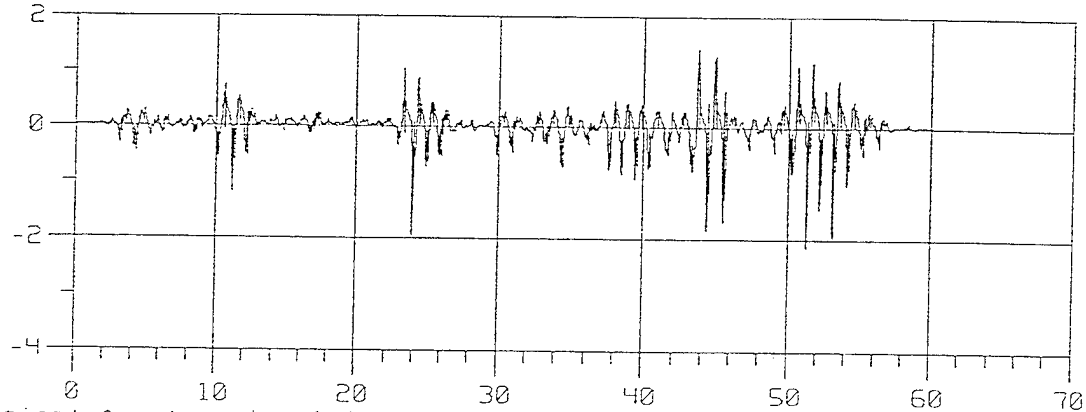


Roll Displacement (deg) vs. TIME (sec)L1

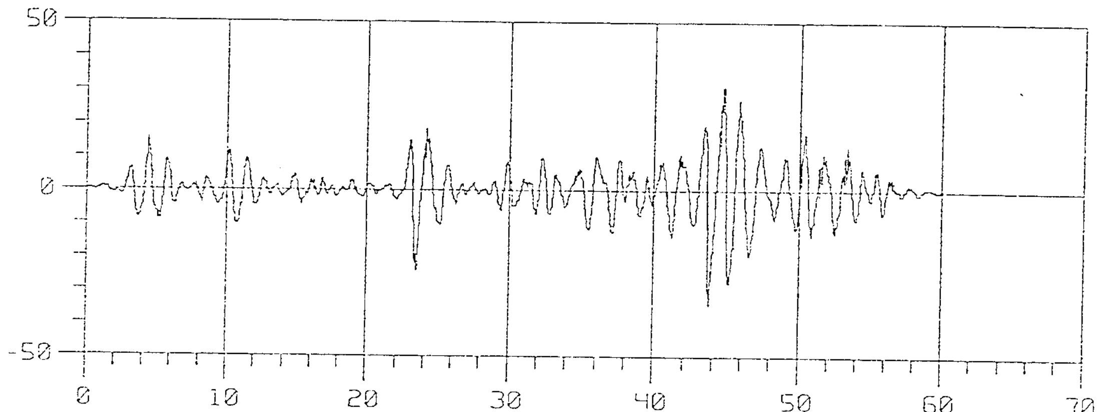


Yaw Displacement (deg) vs. TIME (sec)

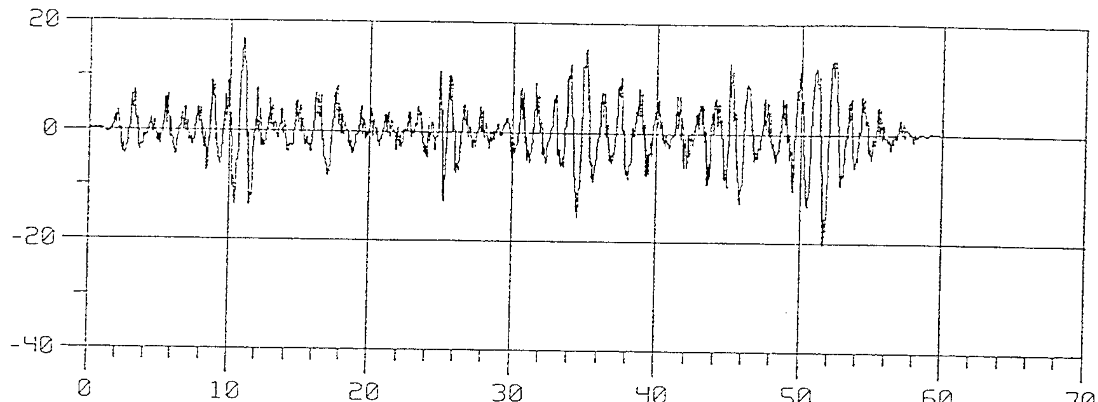
Perryman 2 @ 23 mph



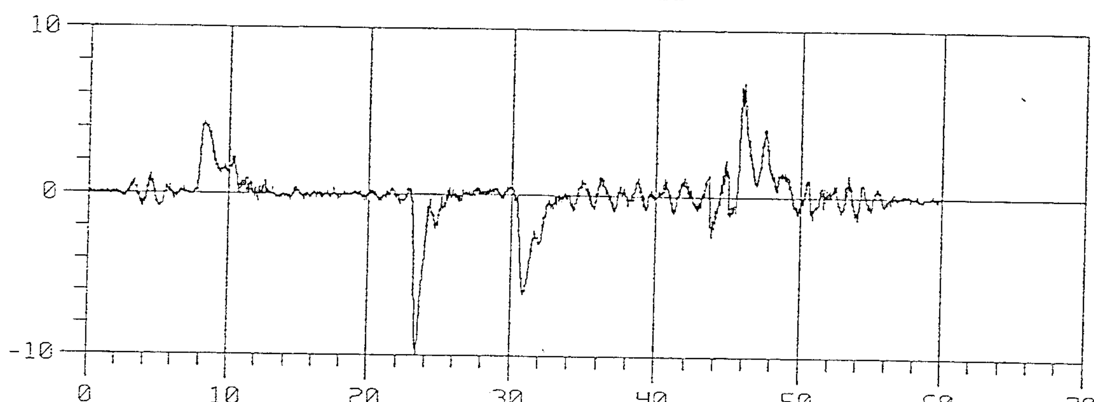
Vertical Acceleration (g) vs. TIME (sec)L1



Pitch Velocity (deg/sec) vs. TIME (sec)

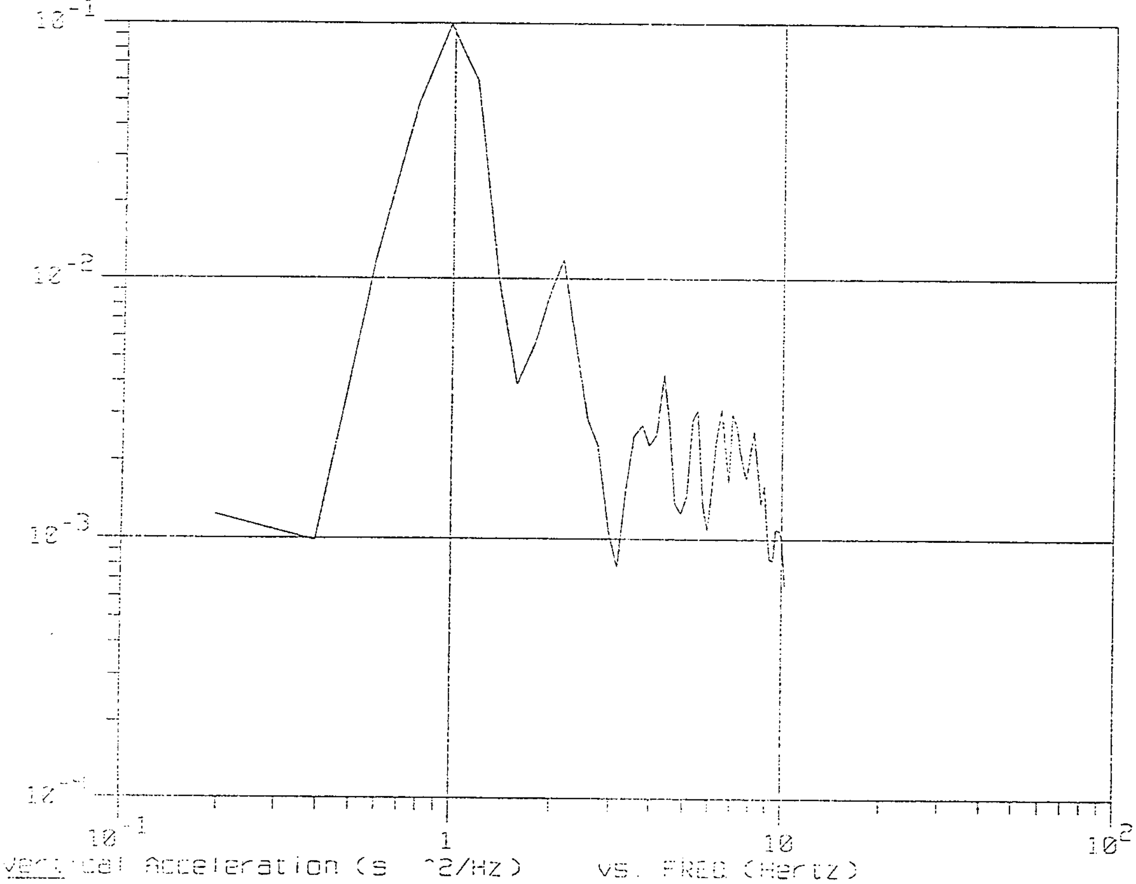


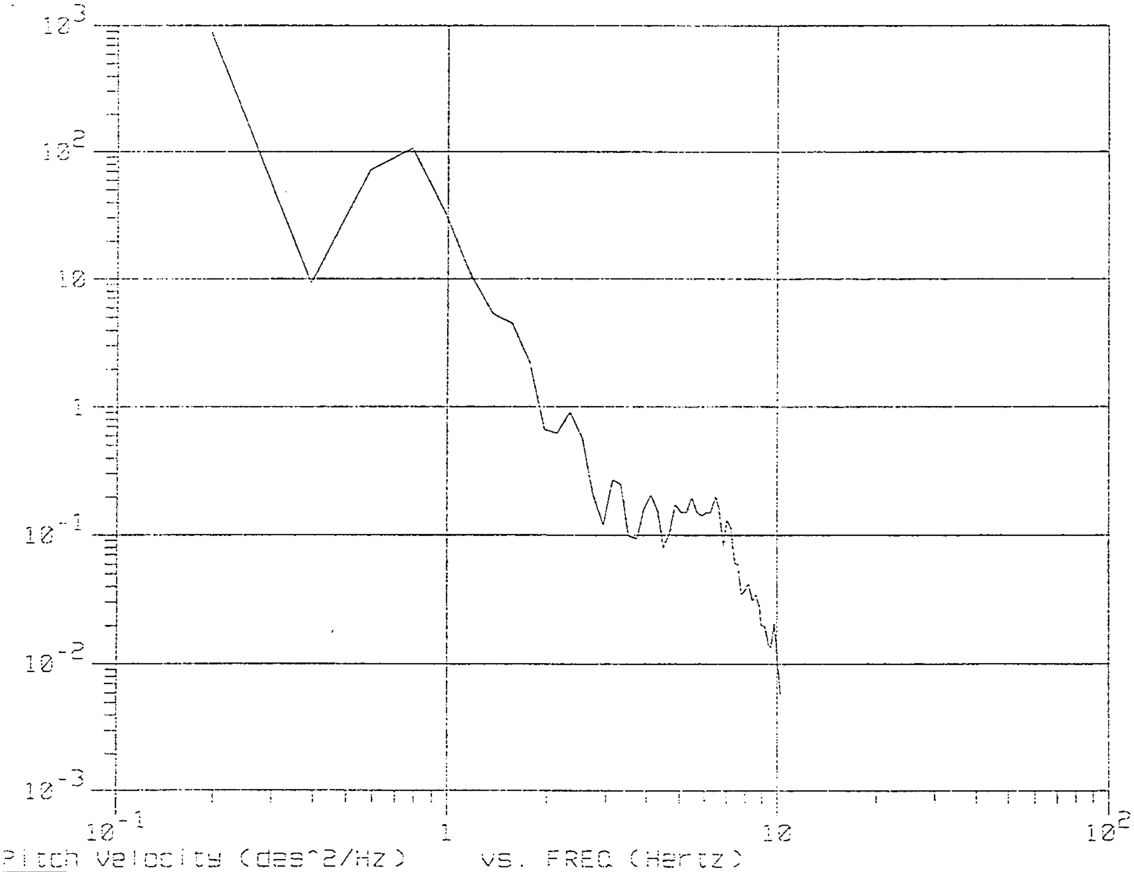
Roll Velocity (deg/sec) vs. TIME (sec)L1



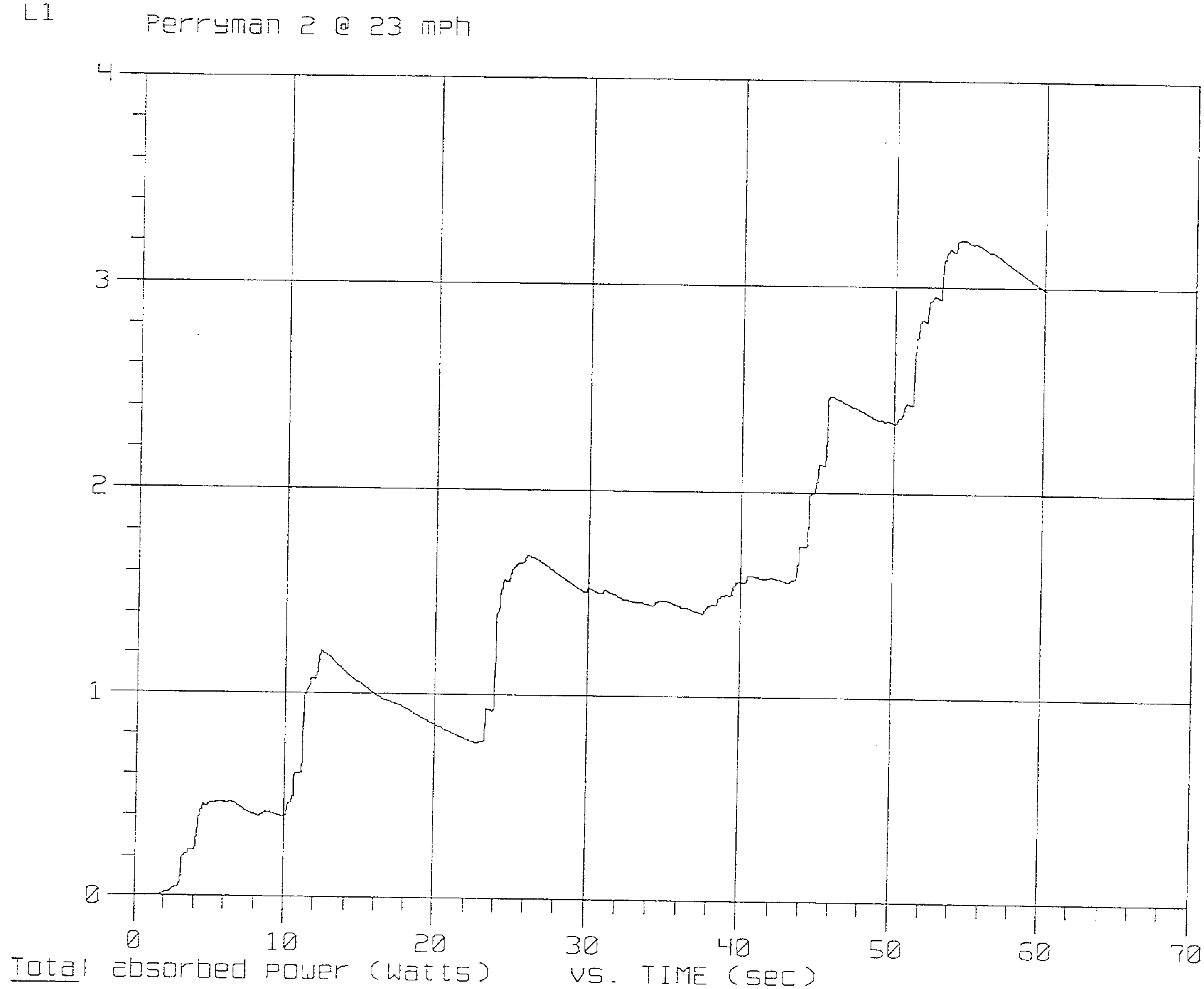
Yaw Velocity (deg/sec) vs. TIME (sec)

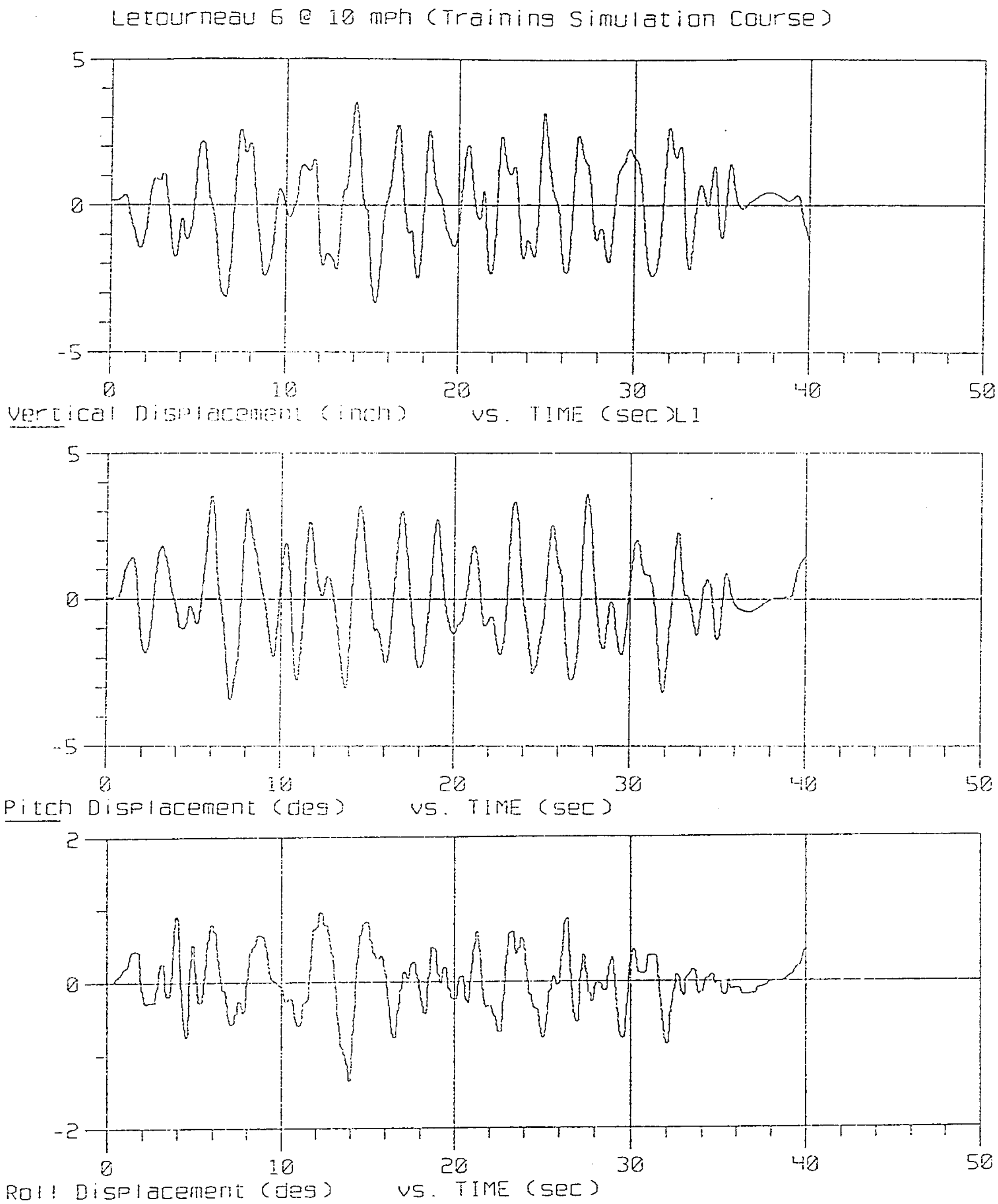
PSD of Perryman 2 @ 23 mph





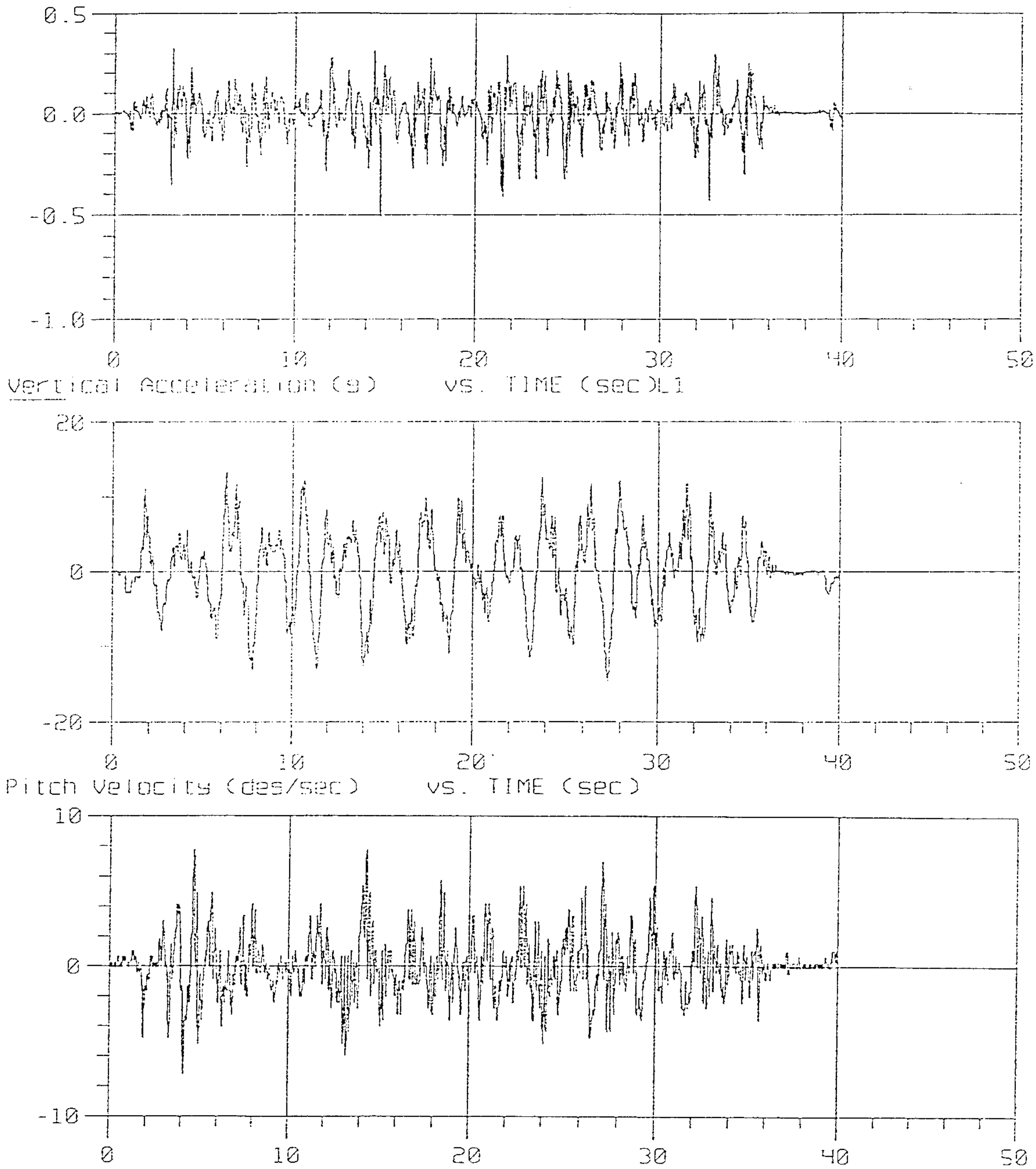
L1

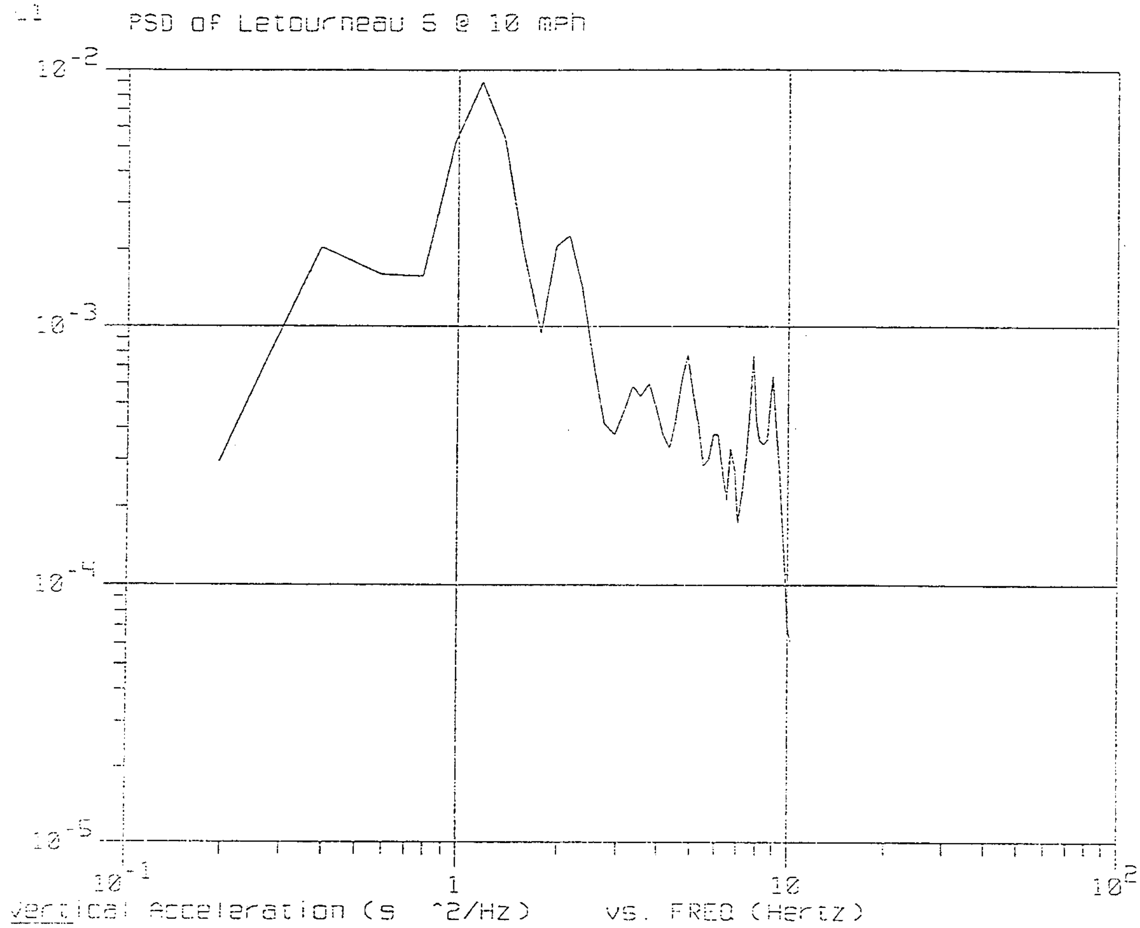

Perryman 2 @ 23 mph
4
3
2
1
0
0
10
20
30
40
50
60
70
Total absorbed power (Watts) vs. TIME (sec)

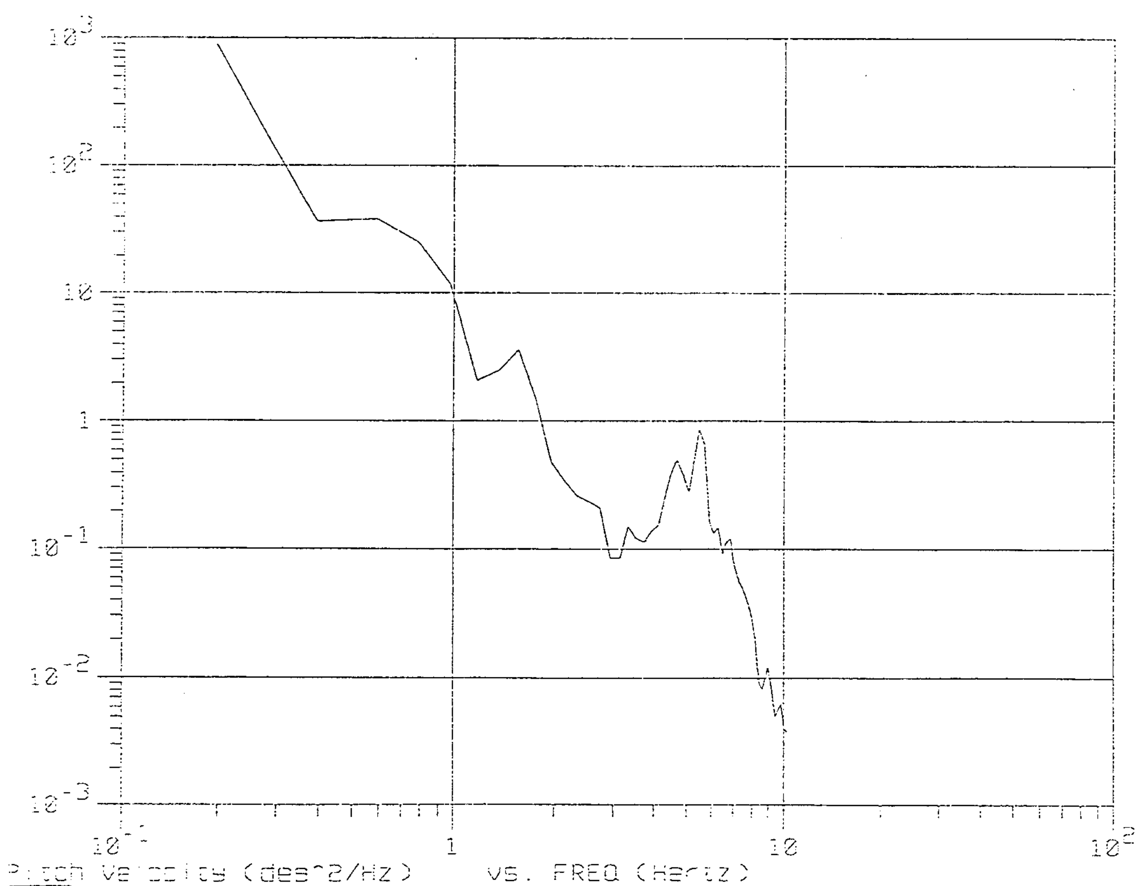


Letourneau 6 @ 10 mph (Training Simulation Course)
5
0
-5
0
10
20
30
40
50
Vertical Displacement (inch) vs. TIME (sec)L1
5
0
-5
0
10
20
30
40
50
Pitch Displacement (deg) vs. TIME (sec)
2
0
-2
0
10
20
30
40
50
Roll Displacement (deg) vs. TIME (sec)

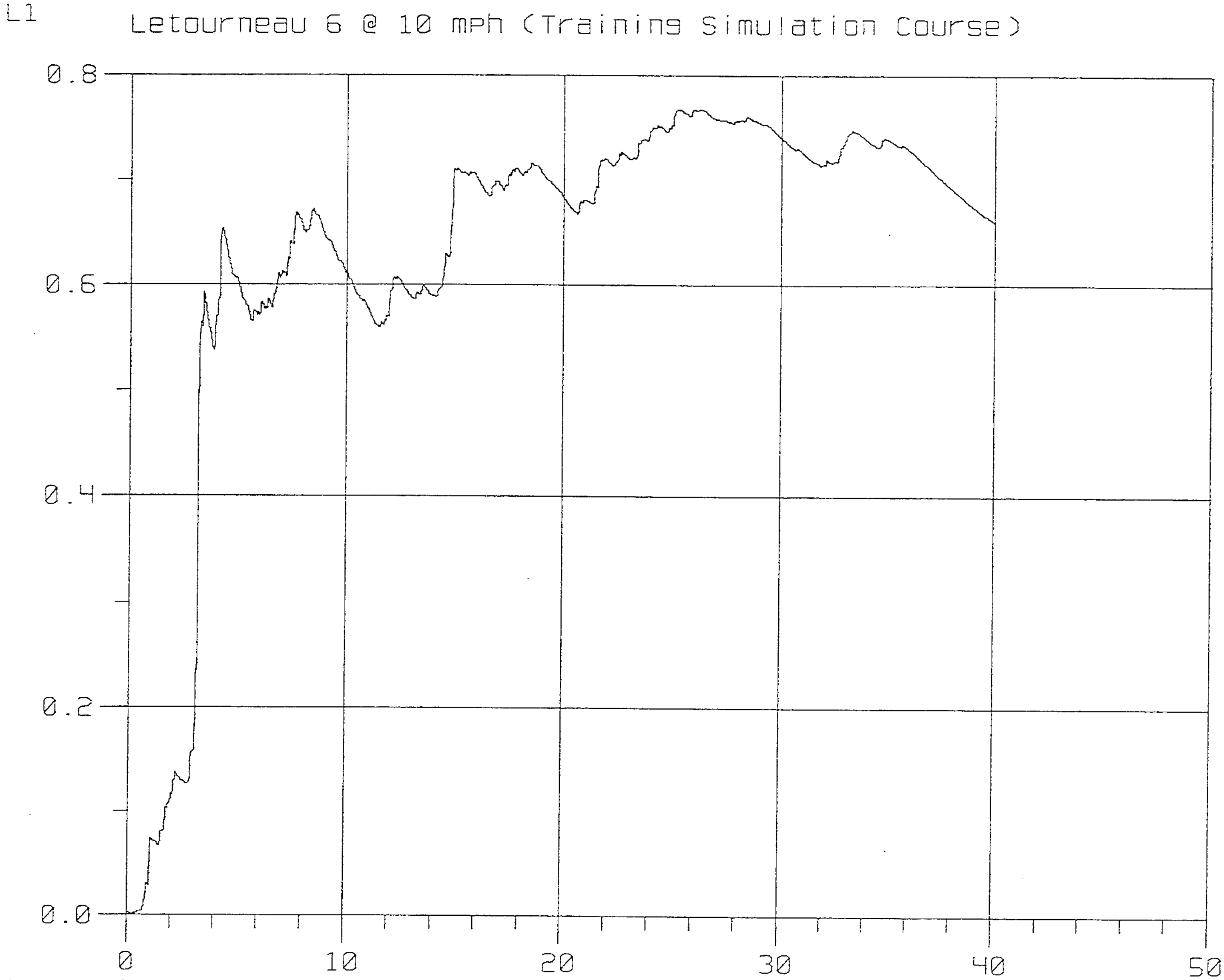
Letourneau 6 @ 10 mph (Training Simulation Course)




PSD of Letourneau 5 @ 10 mph
10^-2
10^-3
10^-4
10^-5
10^-1
1
10
10^2
Vertical Acceleration (s ^2/Hz) vs. FREQ (Hertz)


10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-1
1
10
10^2
Pitch Velocity (deg^2/Hz) vs. FREQ (Hertz)

L1



Total absorbed power (Watts) vs. TIME (sec)

APPENDIX B

Modeling/Drive File Table and Plots

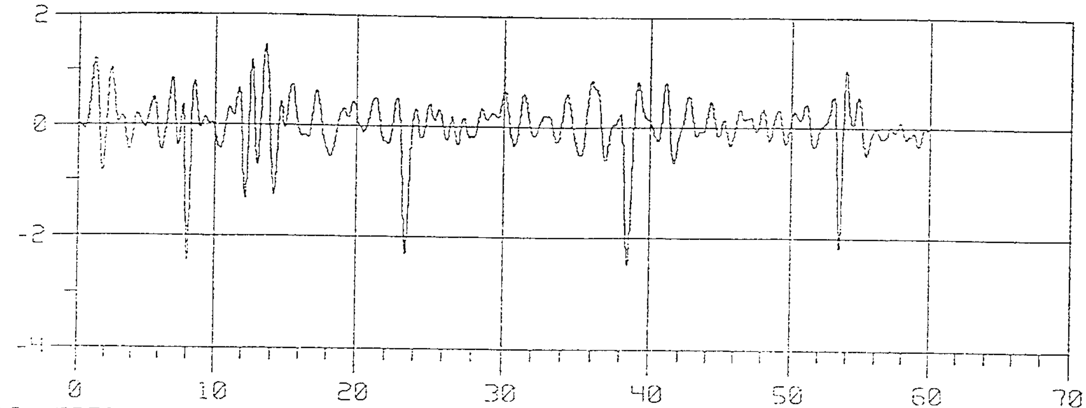
TABLE 9. SIMULATOR DRIVE FILE STATISTICS - TEST RIDES

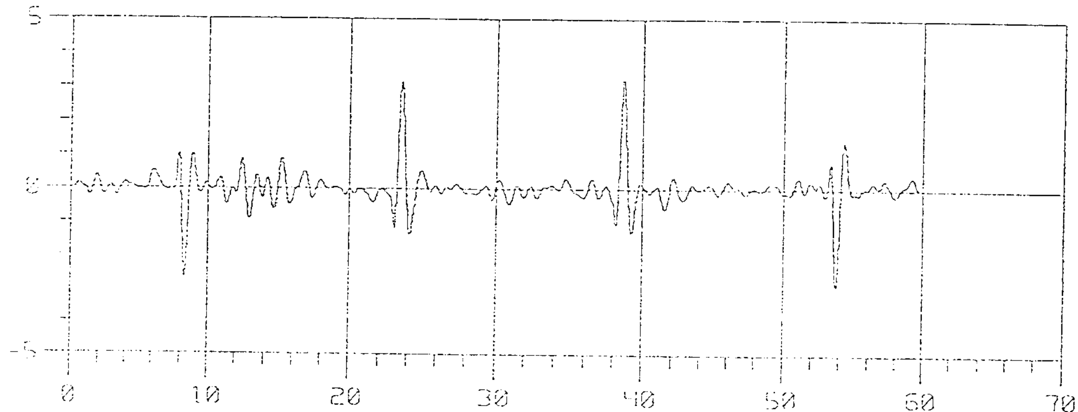
Course	Perryman A @ 40 mph Ride Level 1			Perryman 3 @ 10 mph Ride Level 2			Churchville B @ 12 mph Ride Level 3			Perryman 2 @ 23 mph Ride Level 4		
Command Signal	rms	max	min	rms	max	min	rms	max	min	rms	max	min
Vertical Position(in)	.49	1.43	-2.50	1.94	8.94	-5.27	2.36	8.57	-6.74	2.60	9.61	-10.4
Roll Position(deg)	0.51	3.25	-2.92	.26	0.65	-0.95	0.23	1.30	-0.96	0.90	3.66	-3.20
Pitch Position(deg)	0.29	1.05	-1.74	2.04	5.96	-9.98	2.31	5.21	-9.92	1.45	5.25	-6.56
Yaw Position(deg)	4.73	7.29	-6.98	0.01	0.07	-0.05	0.02	0.08	-0.14	5.73	8.67	-8.68

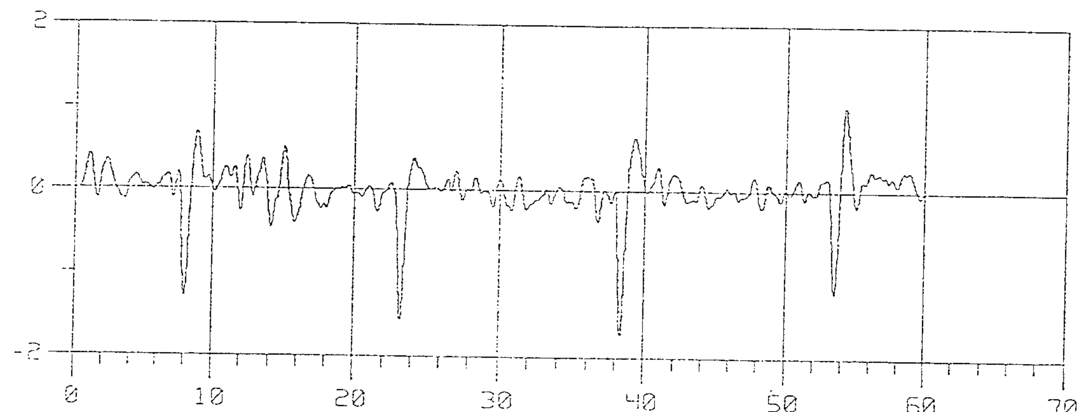
TABLE 10. SIMULATOR DRIVE FILE STATISTICS - TRAINING RIDE

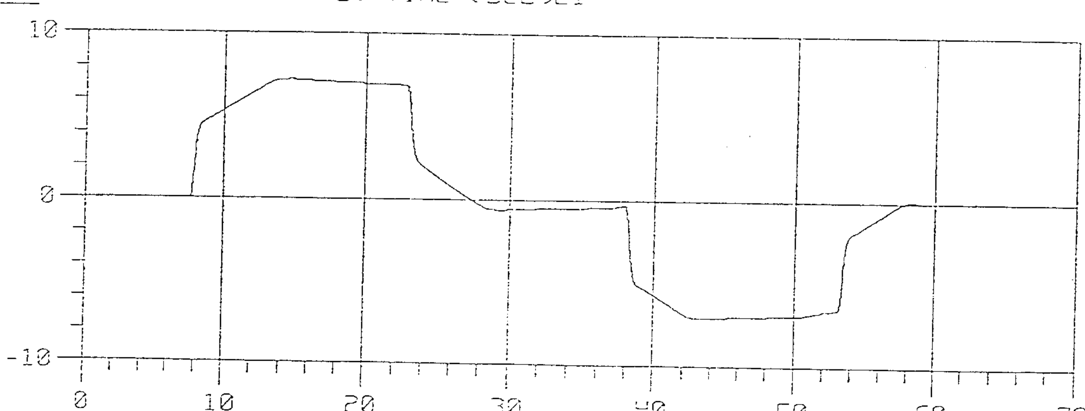
Course	Letourneau 6 @ 10 mph Training Ride		
Command Signal	rms	max	min
Vertical Position(in)	1.58	3.84	-3.72
Roll Position(deg)	0.41	1.36	-0.98
Pitch Position(deg)	1.48	3.44	-3.33
Yaw Position(deg)	0.00	0.00	0.00

L1 Drive File for Perryman A @ 40mph

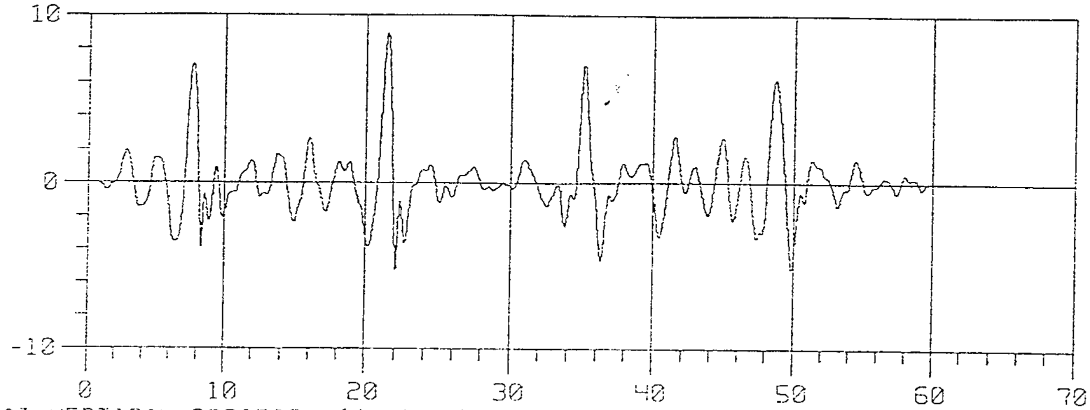




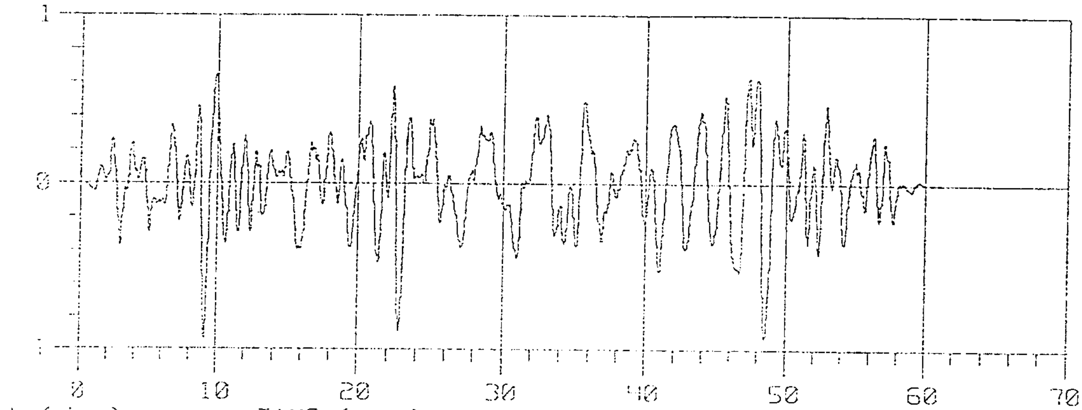




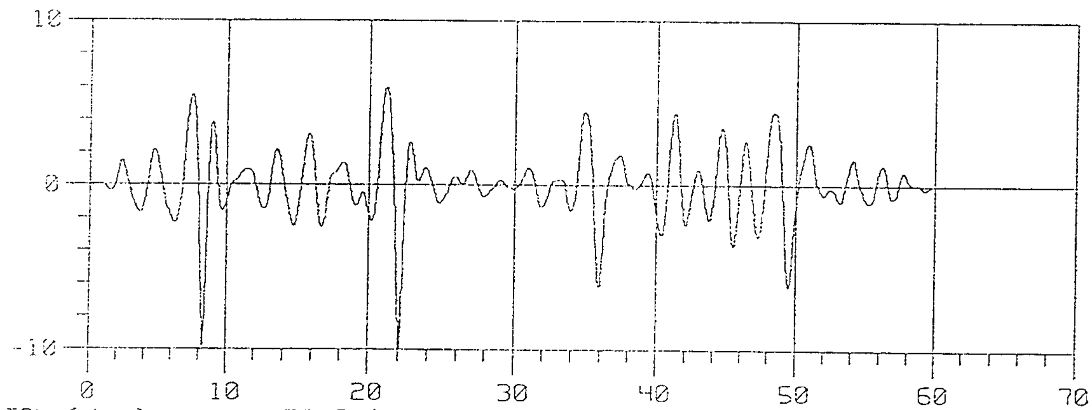
L1 Drive File for Perryman 3 @ 10mph



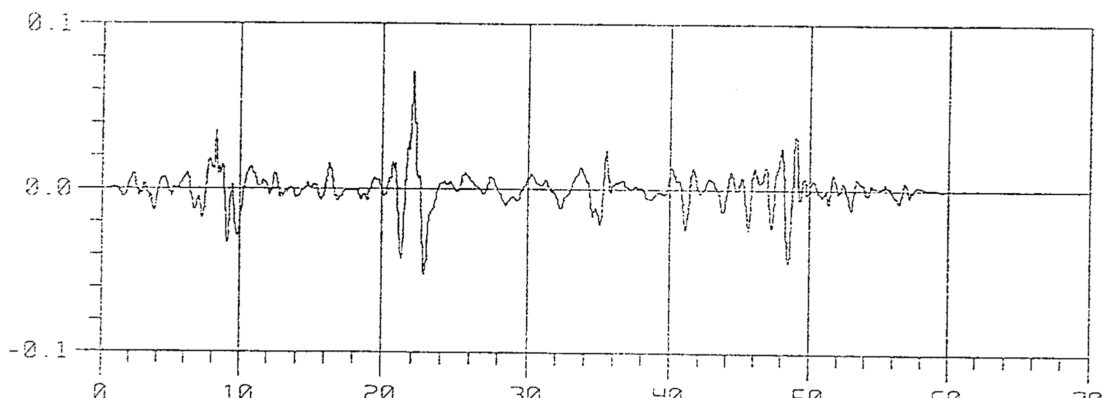
SEAT VERTICAL POSITION (inches) vs. TIME (sec)L1



ROLL (deg) vs. TIME (sec)

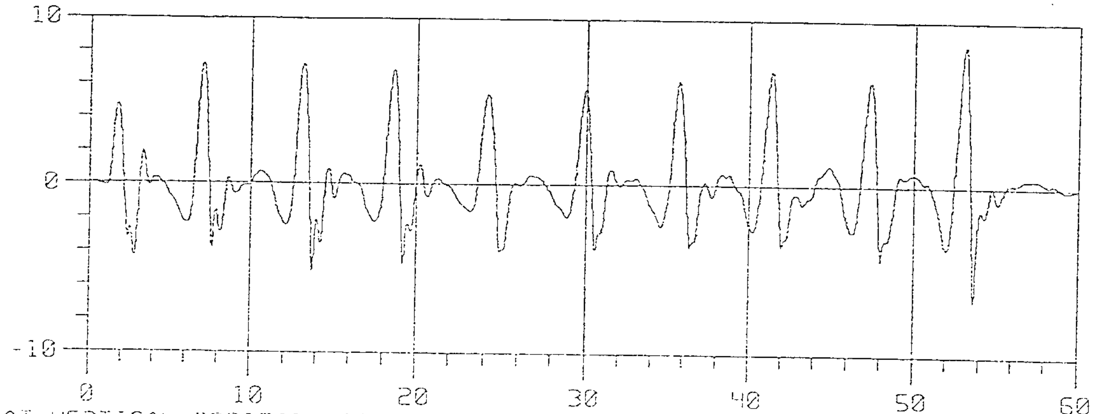


PITCH (deg) vs. TIME (sec)L1

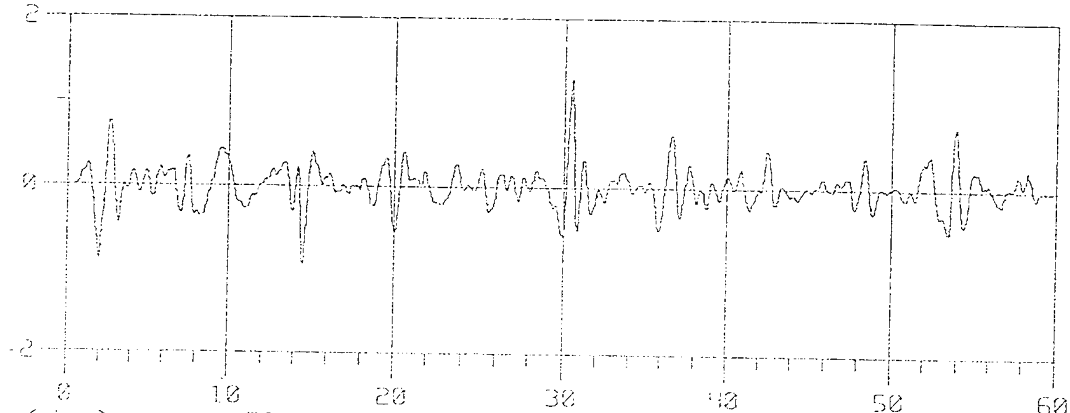


YAW (deg) vs. TIME (sec)

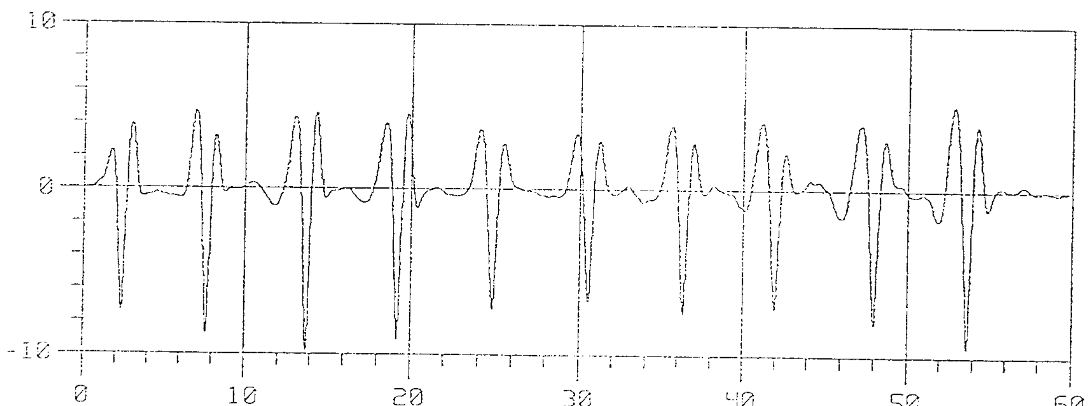
L1 Drive File for Churchville B @ 12mph



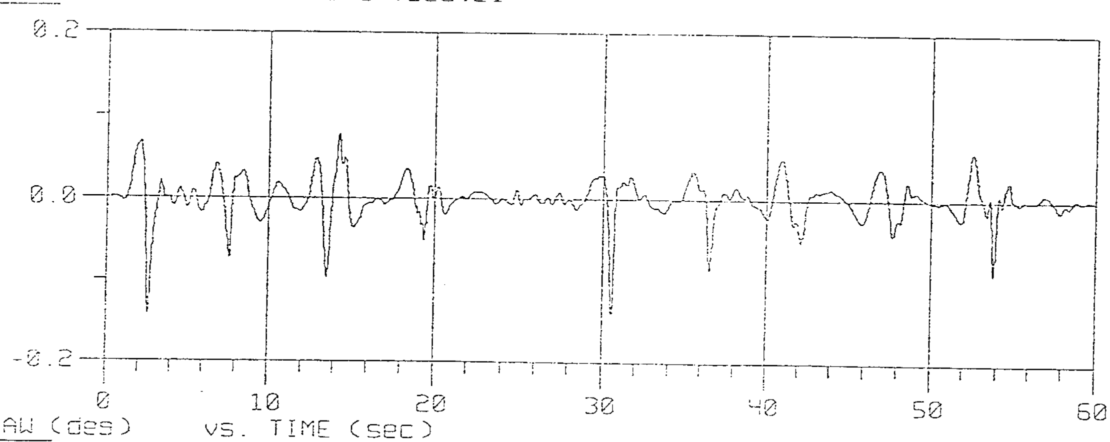
SEAT VERTICAL POSITION (inches) vs. TIME (sec)L1



ROLL (deg) vs. TIME (sec)

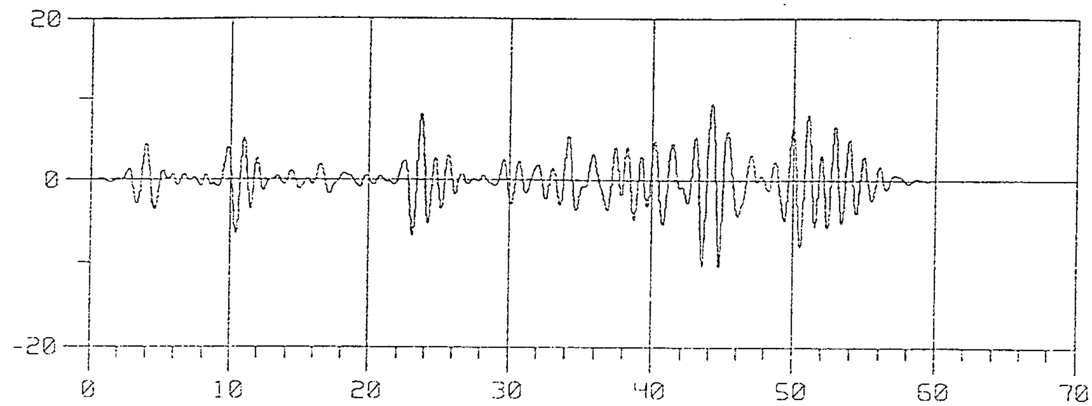


PITCH (deg) vs. TIME (sec)L1

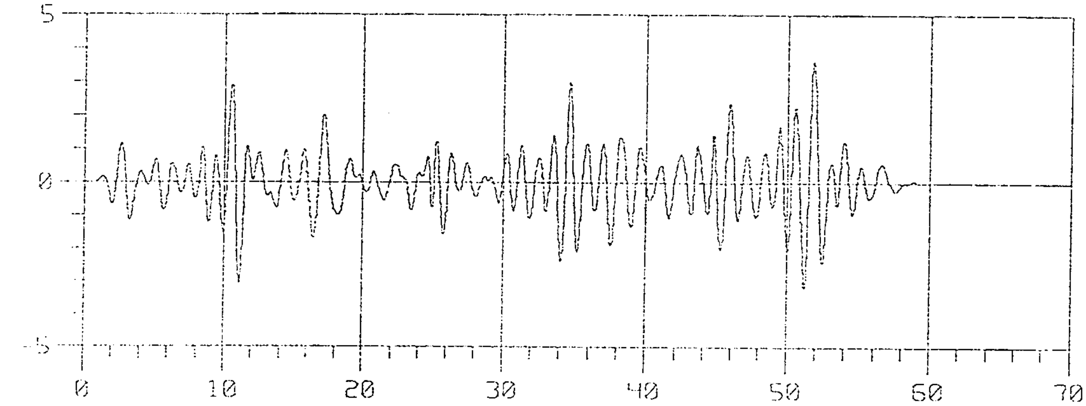


YAW (deg) vs. TIME (sec)

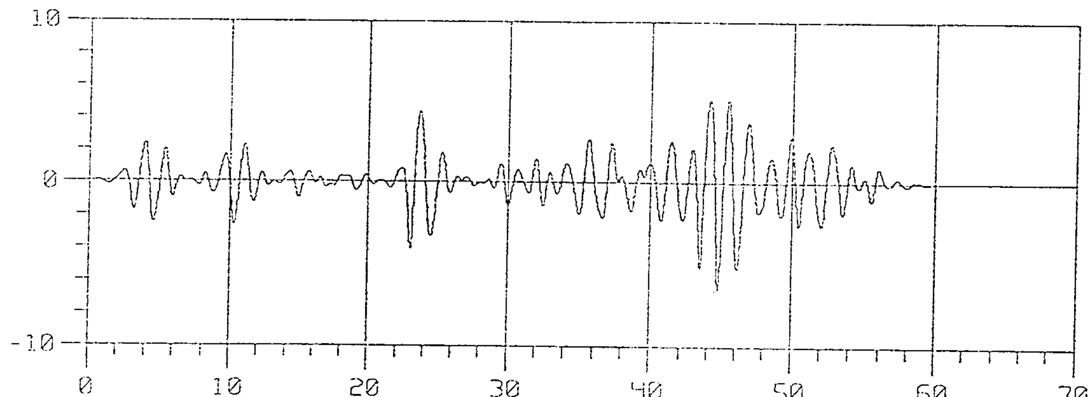
L1 Drive File for Perryman 2 @ 23mph



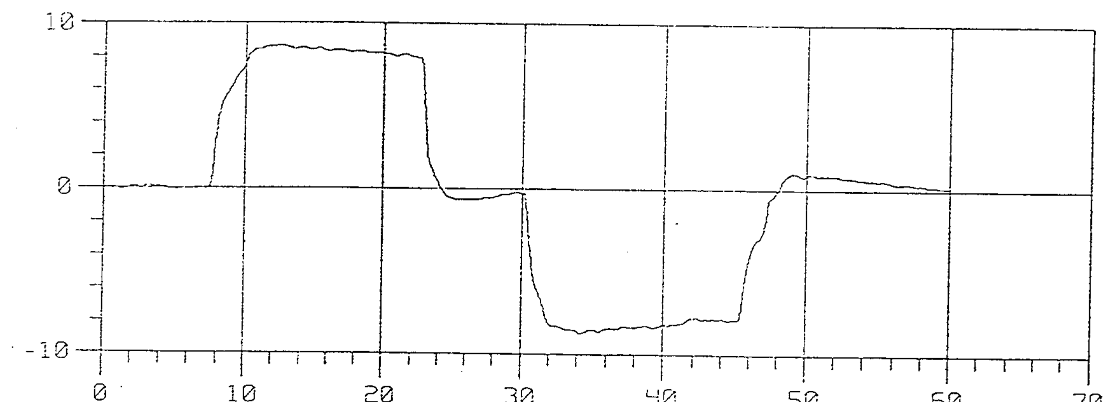
SEAT VERTICAL POSITION (inches) vs. TIME (sec)L1



ROLL (deg) vs. TIME (sec)

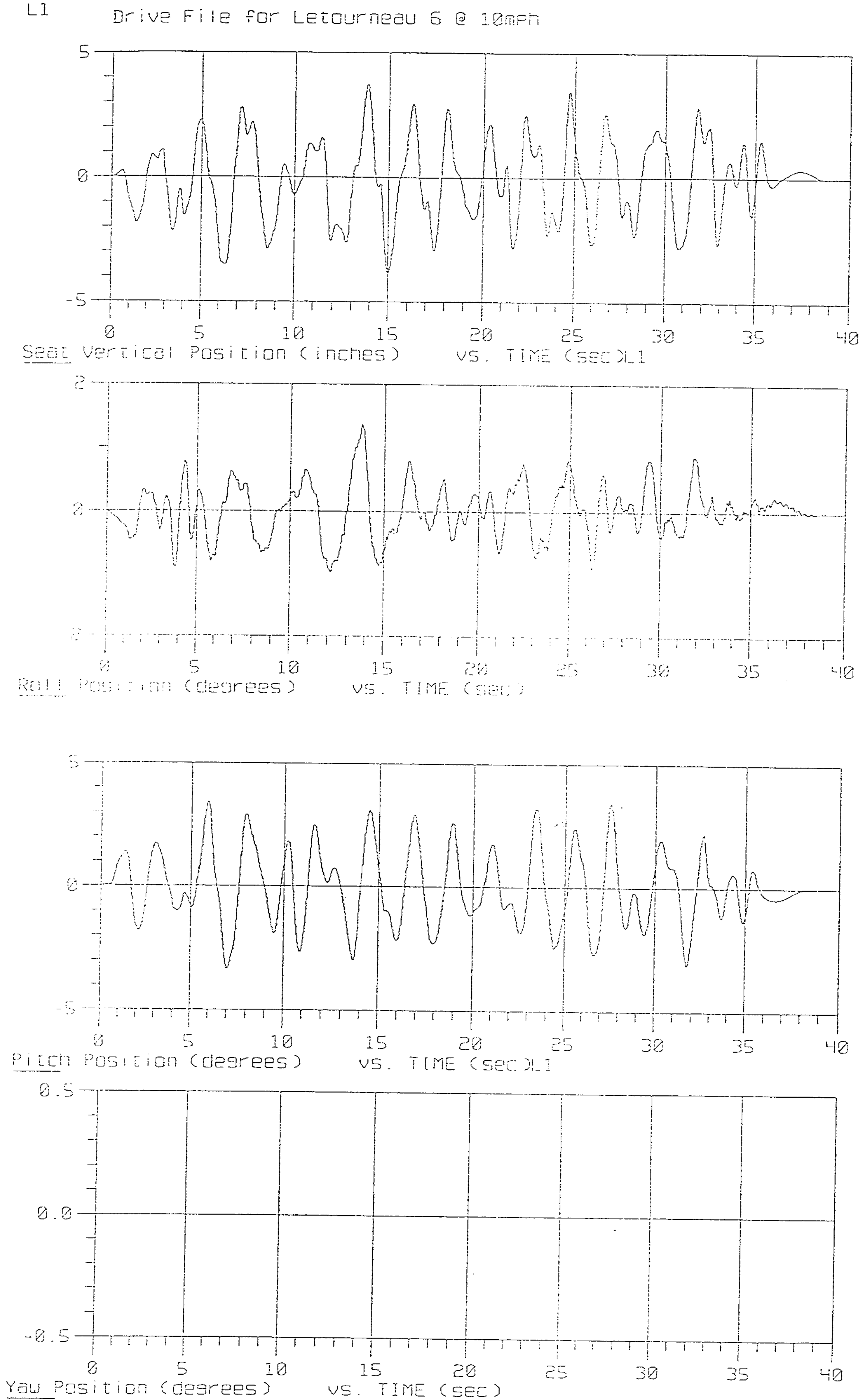


PITCH (deg) vs. TIME (sec)L1



YAW (deg) vs. TIME (sec)

L1


Drive File for Letourneau 6 @ 10mph
Seat Vertical Position (inches) vs. TIME (sec)L1
Roll Position (degrees) vs. TIME (sec)
Pitch Position (degrees) vs. TIME (sec)L1
Yaw Position (degrees) vs. TIME (sec)

APPENDIX C

Sample Run Sheet

Daily Run Sheet

Date: ________ Soldier Name: ______________ Soldier #: ____ Controller: _____ (A=(lear) B=(ESI))

RMS Operators: __________________ HRED Researcher: __________________

TRAINING: Start Time: ________

Filename: [*zero or let6_soldier#_controller_trn_iteration*]

RMS Data Acquisition Filenames:
(zero training ride)

____
____
____
____
____
____

Step 1

3 itertions each
(LET6 training ride)

____
____
____
____
____
____

Step 4

TESTING: End Time: ________

Filename: [*terrain_soldier#_controller_iteration_tst*]

RMS Data Acquisition Filenames:
(zero test)

____
____

Step 2

Step 3 Demo 4 Ride Levels
(1 iteration each)

(Iteration 1 of 4 Ride Levels)

____
____
____
____

Step 5

(Iteration 2 of 4 Ride Levels)

____
____
____
____

Step 6

Step 7 New Gloves
(3 iterations of Let6)

COMMENTS:

APPENDIX D

Test Plan

Project Title: The Effects of Vehicular-Induced Vibration on Turret Slewing and Tracking Performance Using a Fixed Yoke with Thumb-Operated Tracking Control Versus the Conventional Displacement Yoke

Principal Investigator: Monica M. Glumm
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MANPRINT Division
TACOM Field Element
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Location of Study. Ride Motion Simulator
TARDEC
Warren, MI

Timeframe. Start: 16 October 1995
Complete: 3 November 1995

Background.

One of the objectives of the Crewman's Associate program is to develop a crew station that ensures a reduced crew can fight as effectively as a four-man crew by providing improvements in control-display design and their interface with the soldier. This crew station will be integrated into the Future Main Battle Tank.

The Program Manager-Crewman's Associate has requested that the Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL) conduct research examining soldier performance using candidate displays and input-output devices in the motion environment to which the vehicle and the crew will be exposed.

This is the first in a series of studies that are planned by the HRED in support of the goals of the Crewman's Associate program. The purpose of this study is to measure and compare turret slewing and tracking performance with the conventional, displacement yoke ("Cadillac") used in the M1 tank, and a fixed yoke incorporating a thumb-operated tracking control.

Previous research on the Ride Motion Simulator (RMS) has compared gunner performance using the conventional yoke against a fixed joystick incorporating a thumb-operated tracking control (Lee, West, and Glumm, 1980). Performance using the conventional yoke has also been compared with that using a displacement joystick (Sharkey, Schwirzke, McCauley, Casper, and Hennessy, 1995). Generally, the results of these studies indicate that as ride level increases gunner performance will decrease, and that the magnitude of the degradation in performance will vary between control configurations. On most measures, tracking performance with the conventional yoke, was better than that with the thumb-operated or displacement joysticks. Glumm, Singapore, and Lee (1983) found an even greater difference between the yoke and the fixed thumb-operated joystick when subjects operated these controls while wearing chemical protective gloves. Differences in performance between the conventional displacement yoke and joysticks were in part attributed to subject experience with a given control, compensation offered by the second hand in inadvertent control input, and differences in control design characteristics, such as damping.

In this study, it is expected that the additional body stability offered by the fixed yoke and the opportunity to trigger from the left handgrip will reduce inadvertent input to the thumb-control and thus close the gap in performance between it and the conventional displacement yoke.

Objective.

The purpose of this laboratory experiment is to measure and compare the effects of vehicular-induced vibration on turret slewing and tracking performance using a fixed yoke with thumb-operated control versus the conventional, displacement yoke.

The results of this study will assist in the design, assessment, and selection of a multi-function control for Crewman's Associate and ultimately the Army's Future Main Battle Tank.

Subjects.

A total of 30 combat vehicle crewmen from Ft. Knox, KY* will serve as subjects. The Military Occupational Specialty (MOS) of these subjects will be 19K (armor crewman). All will be right-handed and meet visual acuity requirements of 20/20 in one eye and at least 20/100 in the other (corrected or uncorrected). Color vision will also be required.

Apparatus.

Ride Motion Simulator (RMS). The RMS is a hydro-pneumatically actuated simulator, capable of providing the pitch, roll, and yaw motion of a tracked vehicle. The simulator accommodates one individual in an upright seated position, restrained by a seat belt (see Figure 1). For this study, the simulator will be programmed to reproduce rides imparted to the gunner in an M1 tank at various speeds over courses at APG and Churchville. The simulator will provide four levels of ride from a "mild" ride (Ride Level 1) to a more "severe" ride (Ride Level 4). The average watts absorbed power at Ride Level 4 will not exceed 6 watts which is considered an upper acceptable limit for comfort for off-road vehicles (Lee & Pradko, 1968).

Controllers. The two controls to be assessed during this study include the conventional displacement yoke developed by Cadillac Gage Company (see Figure 2) and a fixed, multi-function yoke control developed by Lear which incorporates a thumb-operated isometric button on the right handgrip (see Figure 3). During this study, the thumb control will be used to position the gunner's crosshairs and track targets. A trigger on the yoke's left handgrip will be used to fire on target. Each control type will be mounted on a device that will allow its position to be adjusted vertically and in the fore and aft direction.

Monitor. The "turret" slewing and target tracking tasks to be performed during this study will be presented on a flat panel, liquid crystal display (LCD). The size of the display is 15.2 X 22.9 cm (6 X 9 inches) with a resolution of 480 X 640 lines.

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* Armor crewmen from APG, MD may also serve as subjects as needed.

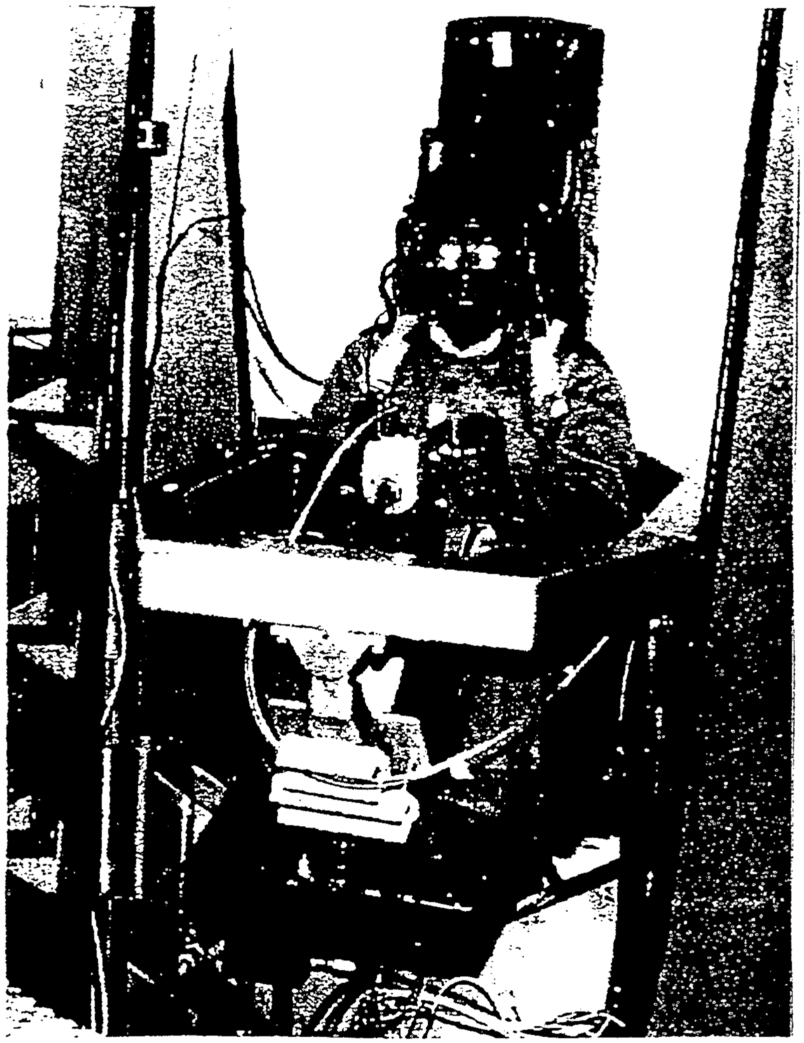

Figure 1. Ride Motion Simulator (RMS)

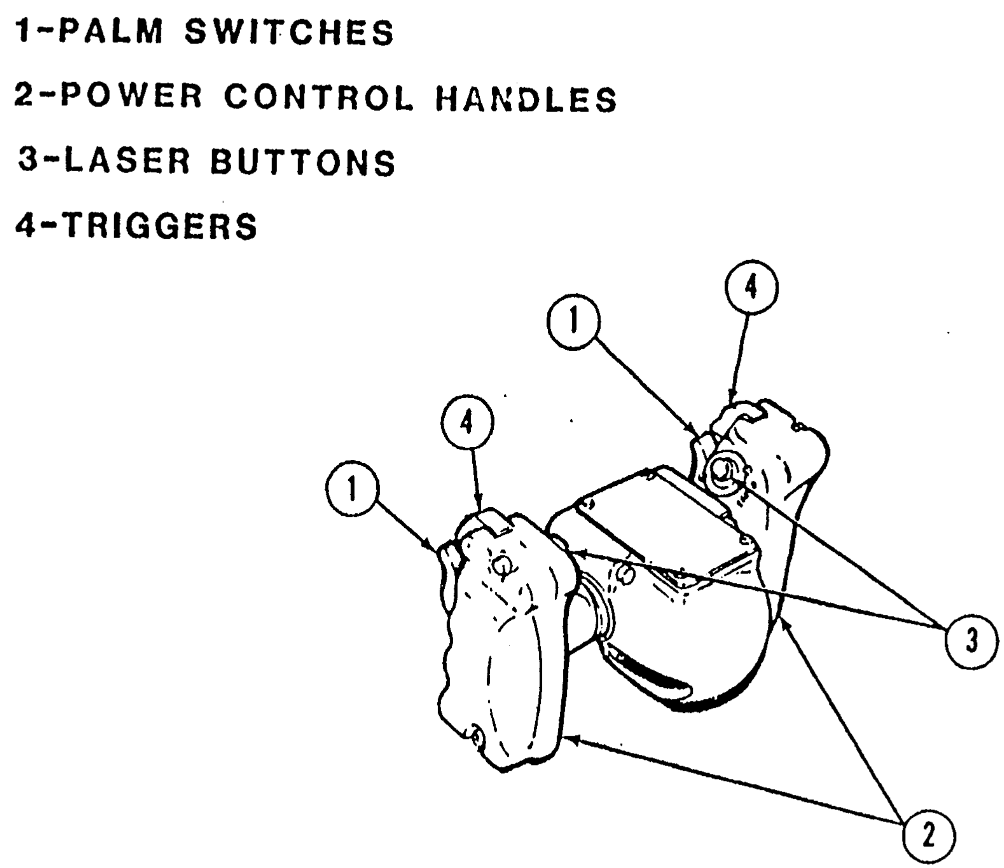

Figure 2. Conventional displacement yoke ("Cadillac").

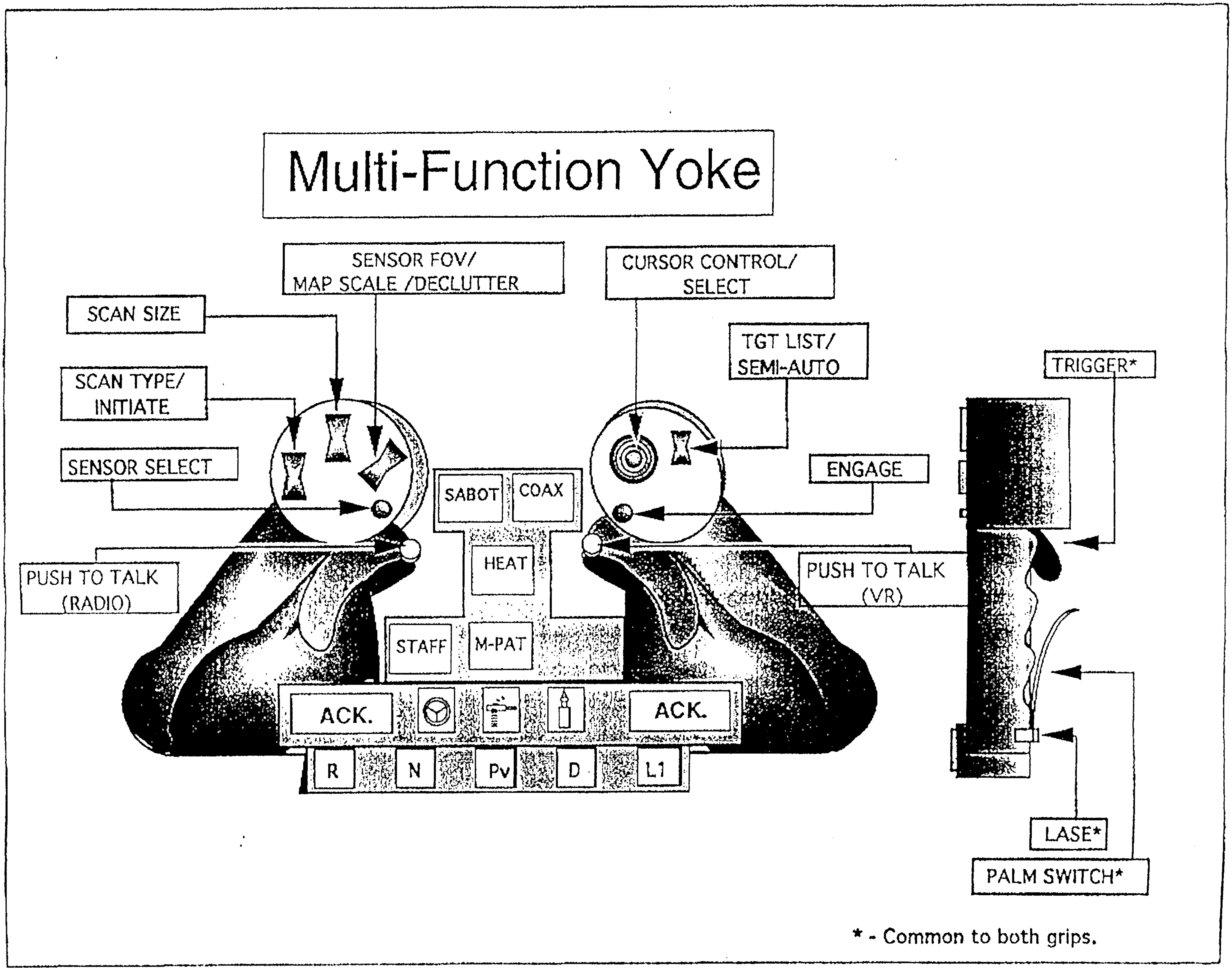

Figure 3. Fixed yoke with thumb-operated tracking control.

Procedure and Methodology.

Subject Screening and Pre-Test Questionnaires. The subjects will be briefed on the purpose of the study, the SOP for the RMS* and other test procedures to be followed, and any risks involved. If they consent to participate, they will be required to sign a Volunteer Agreement Affadavit (Appendix A). A visual acuity and color vision test will be administered to all participants to ensure they meet the vision requirements specified above. All subjects will complete a questionnaire to obtain pertinent demographic and background information (Appendix B). They will also be instructed in the completion of a motion sickness questionnaire (Appendix C). This questionnaire will be administered before, during, and after training and testing to monitor the possible onset of this syndrome.

Training and Test. Fifteen (15) of the 30 subjects who will participate in this investigation will be trained to perform the turret slewing and target tracking tasks with the fixed yoke control and the other 15 subjects will be trained to perform these tasks with the conventional yoke. Two subjects will be run per day. One subject will be trained and tested on one control type in the morning, and the other subject will be trained and tested on the other control type in the afternoon. The control type to be tested in the morning of the first day will be determined by random drawing. This control will be tested in the morning of each odd day of test that follows, whereas the second control will be tested in the morning of each even day.

For each control type, training and testing will first be completed in the stationary or "0" ride level condition prior to training and testing in the four levels of ride motion. After instruction and practice in performing the turret slewing and target tracking tasks, the subject will perform these tasks during consecutive runs until he has attained an asymptote in time to target in the turret slewing task and time on target in the target tracking task. An asymptote will be determined using the moving average technique. The subject will then perform two test runs in the "0" ride level condition. After each of these test runs, for each control type, the subject will complete a questionnaire pertaining to his experience using that control type.

---

* The Standard Operating Procedures for the RMS are contained in the "Users Manual for the RMS" (TR-13464), August 1989.

After completion of training and test in the stationary condition, the subject will then become familiar with performance of the turret slewing and target tracking tasks during one run at each of the four levels of ride motion, starting with the mildest ride (Ride Level 1) and graduating to the most severe ride (Ride Level 4). The subject will then complete consecutive runs at a ride level that represents a midpoint in average watts absorbed power between Ride Levels 1 and 4 until he has reached an asymptote in time to target in the turret slewing task and time on target in the target tracking task.

During testing, the subject will complete two runs at each of the four levels of ride motion for a total of 8 runs. The order of presentation of Ride Levels 1 through 4 will be counterbalanced as shown in Table 1. After each of the 8 test runs, for each control type, the subject will complete a questionnaire to obtain information pertaining to his experience using that control type at that level of ride motion (see Appendix D).

Table 1. Counterbalancing Scheme

CONTROL		ITERATION	
A	B	1	2
Subjects		Ride Levels	
1	16	4 2 3 1	1 2 4 3
2	17	2 3 4 1	4 3 2 1
3	18	2 1 4 3	1 4 2 3
4	19	3 2 1 4	2 1 3 4
5	20	3 1 2 4	3 2 4 1
6	21	1 3 2 4	4 3 1 2
7	22	4 2 1 3	2 3 1 4
8	23	2 4 3 1	3 4 2 1
9	24	1 3 4 2	1 2 3 4
10	25	4 1 2 3	4 1 3 2
11	26	1 4 3 2	2 4 1 3
12	27	3 4 1 2	3 1 4 2
13	28	1 4 2 3	3 1 2 4
14	29	2 1 3 4	1 4 3 2
15	30	3 2 4 1	2 3 4 1

Turret Slewing and Target Tracking Tasks. The duration of each run at each ride level will be 2 minutes in which the same 60 second ride will be repeated twice. During the first minute of each run, the subjects will perform the "turret" slewing task. During this period a total of six targets will be presented. One target will be presented every 10 seconds and displayed for a duration of 8 seconds. The targets will appear at the same times in each run but the locations at which these targets will appear on the display will be randomized within and between runs. Upon the presentation of each target the crewman will slew his crosshairs on to the target as rapidly and accurately as possible and depress the firing trigger. Upon depression of the trigger, the target will disappear from the screen. The target will also disappear from the screen if it has not been fired upon within the 8 second period. In this latter instance, the target will be scored as a miss and flagged. Time to lay will be based on time from target presentation to trigger pull. Lay error at trigger pull will also be measured. For the turret slewing task an average frequency, amplitude, and watts absorbed power will be computed from the time the target is presented to the time of trigger pull.

During the second minute in each run, subjects will perform the target tracking task. During this period three targets will be presented one at a time. One of these targets will remain stationary, the other will take a straightline path to the right and then to the left in the display (or vica versa), and the third will move evasively in a sine wave-like maneuver (see Figure 4). All moving targets will move at a constant speed. The targets will be the same size as those presented during the turret slewing task. The size of the target will be 5.5 mm square which subtends the same visual angle as an M1 tank (side view, gun forward) at 2500 m as seen through an M1 daysight at 3X (wide field of view). Each of these targets will be presented for a duration of approximately 15 seconds. The location at which these targets will appear on the crewman's display and the type of movement they will make (i.e. stationary, straightline, or evasive) will be randomized among runs. Upon the presentation of each target the crewman will slew his crosshairs on to the target as rapidly and accurately as possible, and depress the firing trigger. The subject will be required to maintain his crosshairs on the target and pull the trigger as often as he is assured that he has achieved a good lay. Lay error, time on target, and the percent of hits to the number of trigger pulls will be computed. The average frequency, amplitude, and watts absorbed power will be computed from the time the target is presented to the time of first trigger pull, and for the period between subsequent trigger pulls (i.e. TP1 to TP2, TP2 to TP3, etc.).

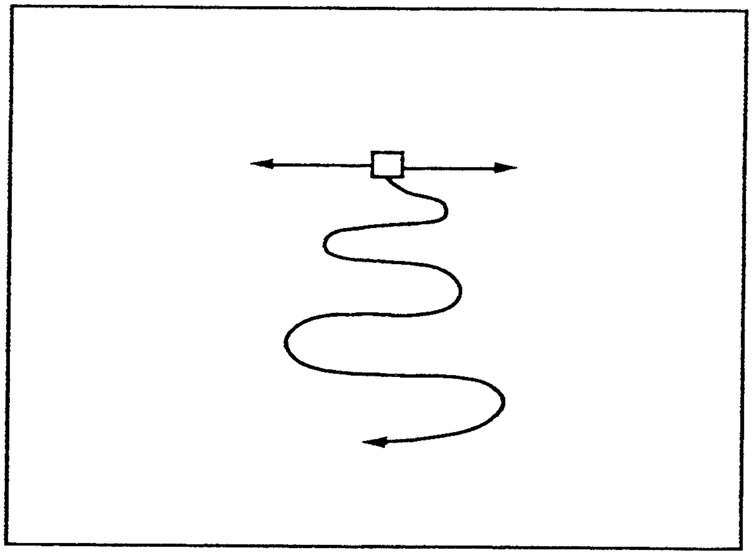

Figure 4. Target motion scenarios.

Experimental Design.

The design matrix is shown in Figure 5. The study will be a 2 x 5 factorial (control type x ride level) mixed design with control type as a between-subjects variable and ride level as a within subjects variable. The two control types will be the fixed yoke with thumb-operated tracking control and the conventional displacement yoke. The five ride conditions, which include the stationary or "0" ride level as well as the four levels of ride motion, are described in Table 2 (to be provided). The presentation of control type and the four levels of ride motion will be counterbalanced. The dependent variables will be frequency, amplitude and watts absorbed power, and the following measures of turret slewing and target tracking performance:

Turret slewing - Time from target presentation to trigger pull
Lay error at trigger pull

Target tracking - Lay error at trigger pull
Time on target
Percent hits to trigger pulls

CONTROL TYPE		Subjects	RIDE LEVEL									
			0	1	2	3	4	0	1	2	3	4
	Thumb-Operated Control (Fixed Yoke)	1 → 15										
	Displacement Yoke	16 → 30										

Figure 5. Design matrix.

Data Analysis.

The data will be analyzed using regression techniques. Control type will be entered into the regression equation using dummy coding. The independent variables that quantify vibration (e.g. watts absorbed power, frequency, and amplitude) will be entered if significant and their linear quadratic and cubic effect on the dependent variables examined. A goodness of fit will be used to determine an adequate model. Outliers and colinearity issues will be examined using Durbin, Watson, and Cook's D statistic.

Participant Scenario.

Two subjects will be run per day. The length of each subject's participation will be approximately four hours. The following represents a daily agenda for two subjects:

Daily Agenda

0800-0845 (Subjects 1 and 2)	Administrative • Visual Acuity Test • Study and risk description • Signing of Volunteer Affadavit Agreement • Pre-Test Questionnaire • Instruction on Motion Sickness Questionnaire
0845-0945 (Subject 1)	Training and Testing on Control A or B: Ride Level 0 (Stationary) * • Instruction on turret slewing and target tracking tasks • Training to asymptote • Testing (2 runs)
0945-0955	Break (10 minutes)
1000-1130 (Subject 1)	Training and Testing on Control A or B: Ride Levels 1 - 4 (Moving) * • Training on Ride Levels 1 - 4: 1 run at each ride level • Training to asymptote: consecutive runs at a ride level which represents a midpoint between Ride Levels 1 and 4. • Testing: Iteration #1 (1 run at each level of ride motion) • Break (10 minutes) • Testing: Iteration #2 (1 run at each level of ride motion)
1130-1200 (Subject 1)	Post-Test Questionnaire and Debriefing

1200-1300	Lunch
1300-1400 (Subject 2)	Training and Testing on Control A or B: Ride Level 0 (Stationary) * - as above for Subject 1
1400-1410	Break (10 minutes)
1410-1540 (Subject 2)	Training and Testing on Control A or B: Ride Levels 1 - 4 (Moving) * - as above for Subject 1
1540-1610 (Subject 2)	Post-Test Questionnaire and Debriefing

* The motion sickness questionnaire will be administered immediately before commencement of training and after each test run in no-motion and motion conditions. A post-run questionnaire will also be administered after each test run to obtain information as to the subject's experience during that run using that control type.

Risk.

There are two risks associated with this experiment. First, for this study, the simulator will impart rides recorded at the gunner's seat in the M1 tank at various speeds over test courses at APG and Churchville. These rides can be rough at times but not unlike those experienced or to be experienced in an operational environment by armored crewmen like those who will participate in this investigation.

It should also be noted that TARDEC's Ride Motion Simulator has been successfully used in the past, without incident, by the HRED and recently by others in the conduct of similar type research. The Ride Motion Simulator has been "man-rated" and a safety release issued (see Appendix E). Each participant will be required to wear a CVC helmet and a seatbelt during all motion conditions. The seatbelt is a three-point harness with shoulder straps and lap belt.

Secondly, when a visual display is presented in a dynamic environment, there is always the risk of simulator or motion sickness. The subjects will be informed of this prior to participation and told that they may withdraw at any time during the experiment for this or any other reason. Symptoms that may indicate the onset of motion sickness will be monitored by experimenters throughout the study. Vomitus receptacles will be available at the study site. Any used receptacles will be considered a biohazard and will be handled and disposed of in accordance with applicable health regulations. This will be coordinated with TACOM's Health Clinic. Anyone handling such biohazard material will be clothed appropriately to include the use of protective gloves.

Bibliography.

Glumm, M. M., Singapore, M., and Lee, R. A. (1983). Evaluation of combat vehicle gunner performance with various combinations of NBC protective apparel: a laboratory study (TR-12714). Warren, MI: U. S. Army Tank-Automotive Command Research and Development Center.

Lee, R. A., West, W. D., and Glumm, M. M. (1980). Evaluation of gunner station configurations for firing on the move (TR-12520). Warren, MI: U.S. Army Tank-Automotive Research and Development Command.

Lee, R. A., and Pradko, F. (1968). Analytical analysis of human vibration (680091). Detroit, MI: Society of Automotive Engineers.

Reid, A. A. (1989). Users manual for the RMS (TR - 13464). Warren, MI: U.S. Army Tank-Automotive Command Research and Development Center.

Sharkey, T. J., Schwirzke, M. F., McCauley, M. E., Casper, P., and Hennessey, R. T. (1995). Effects of whole body motion, handcontrol device, and head mounted display on tracking performance. Cary, NC: Monterey Technologies, Inc.

Appendix A

Volunteer Agreement Affadavit

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25 or AR 40-38, the proponent agency is OTSG

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087

Principle Purpose: To document voluntary participation in the Clinical Investigation and Research Program SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study, implementation of medical programs, adjudication of claims, and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A(1) - VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________________, SSN ______________,

having full capacity to consent and having attained my ______________ birthday, do hereby volunteer/give consent as legal

representative for ______________________________ to participate in The Effects of Vehicular-Induced Vibration on Turret Slewing and Tracking Performance Using a Fixed Yoke with Thumb-Operated Tracking Control Versus the Conventional Displacement Yoke

(Research study)

under the direction of Monica Glumm or Moshin Singapore

conducted at the Tank-Automotive Research, Development & Engineering Center.

(Name of Institution)

The implications of my voluntary participation/consent as legal representative; duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

______________________________.

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury, I may contact

Department of the Army, U.S. Army Research Laboratory, ATTN: Office of Chief Counsel

at 2800 Powder Mill Road, Adelphi, MD 20783-1197 (301)-394-1070, (DSN) 290-1070

(Name, Address and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefits; however, I/the person I represent may be required (military volunteer) or requested *(civilian volunteer)* to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

PART A (2) - ASSENT VOLUNTEER AFFIDAVIT *(MINOR CHILD)*

I, ______________________________, SSN ______________ having full

capacity to assent and having attained my ______________ birthday, do hereby volunteer for ______________

______________________________ to participate in ______________

USE OF MINORS IS NOT AUTHORIZED FOR HRED RESEARCH

(Research Study)

under the direction of ______________________________

conducted at ______________________________

(Name of Institution)

(Continue on Reverse)

VOLUNTEER AFFIDAVIT (MINOR CHILD) (Cont'd.)

The implications of my voluntary participation; the nature, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

USE OF MINORS IS NOT AUTHORIZED FOR HRED RESEARCH

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights I may contact

at

(Name, Address, and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my assent and withdraw from the study without further penalty or loss of benefits; however, I may be requested to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

PART B - TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.)*

The purpose of this study is to measure your ability to slew onto targets and track them using two different controls. One control is a fixed yoke with a thumb-operated tracking control on the right handgrip. The other control is a moveable yoke which is rotated to either the left or right and up or down. For both controls, triggering is performed from the left handgrip.

During the study, you will operate these controls wearing the standard Nomex gloves while seated in a ride simulator that has been programmed to reproduce the ride of an M1 tank traveling at various speeds over different terrain. You will be required to wear a CVC helmet and seatbelt at all times while seated in the ride motion simulator. During the study, you will be trained and tested in the performance of the turret slewing and target tracking tasks using each of the two controls first without and then with ride motion. During testing with ride motion, you will experience four different levels of ride. These rides are similar to those you might have experienced in the M1 tank but because the rides and display may not completely match your expectations, there is always the risk that you may become motion sick. Therefore, after each ride, we will ask that you complete a questionnaire to tell us how you feel at that moment. Any incidents of motion sickness will be followed up by a 1 hour observation period during which the driving of any motor vehicle is strongly discouraged. This is to preclude any potential flashback effects, which have been known to occur in some cases.

SEE CONTINUATION SHEET

I do ☐ do not ☐ *(check one & initial)* consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER	DATE	SIGNATURE OF LEGAL GUARDIAN *(If volunteer is a minor)*	
PERMANENT ADDRESS OF VOLUNTEER	TYPED NAME OF WITNESS		
	SIGNATURE OF WITNESS		DATE

Continuation Sheet:

Air Sickness Bags will be available at the test site in case you become motion sick.

The Standard Operating Procedures for the RMS will be briefed to you. These procedures are contained in the "Users Manual for the RMS" which is available on site for you to review.

We anticipate that your total time for participation in this study will not exceed one day.

In order to participate in this study, you must be right-handed and have 20/20 vision in one eye and at least 20/100 in the other eye with or without eyeglasses or contacts.

Appendix B

Pre-Test Questionnaire

PRE-TEST QUESTIONNAIRE

Please answer the following questions. The information you provide will be kept *<u>CONFIDENTIAL.</u>*

1. Name: ____
   Last First Middle Initial

2. Age: ____________

3. Rank: ____________________

4. Military Occupational Specialty (MOS): __________________

5. Time in Service: _______years _________ months

6. Time in grade: ________years _________ months

7. Time in MOS: ________years _________ months

8. Are you left- or right-handed?

   Left-Handed [ ] Right-Handed [ ]

9. Do you wear eyeglasses or contacts?

   Yes [ ] No [ ]

10. How many times have you fired the tank main gun?

0	[ ]
1 - 5	[ ]
6 - 10	[ ]
11 - 20	[ ]
20 or more	[ ]

If you have answered " 0" to Question #10, move on to Question#19.

11. From which crew position did you fire the main gun?

Commander	[ ]
Gunner	[ ]
Both	[ ]

12. When was the last time you fired the main gun? ____________

Less than a week ago	[ ]
Less than a month ago	[ ]
Less than six months ago	[ ]
More than a year ago	[ ]

13. Have you fired the main gun in combat?

Yes [ ] No [ ]

14. Have you done any firing on the move?

Yes [ ] No [ ]

If Yes, how many times have you fired the main gun on the move? ________ times

15. When was the last time you fired Level I gunnery?

________ years? ________ months? ________weeks?

16. Did your crew qualify in the last Level I gunnery?

Yes [ ] No [ ]

17. When was your most recent gunnery training?

________ years? ________ months? ________weeks?

18. Were you a member of the NET team?

Yes [ ] No [ ]

19. How often do you play video or arcade games? *(Check one)*

Everyday	[ ]
1 - 3 times a week	[ ]
1 - 3 times a month	[ ]
1 - 3 times a year	[ ]
Not at All	[ ]

If you answered "Not at All" to Question #19, go to Question #25.

20. Where do you play video or arcade games?

Home	[ ]
Arcade	[ ]
Both	[ ]

21. On the average, when you do play video or arcade games, about how long do you play them?

Less than 2 hours	[ ]
3 - 5 hours	[ ]
6 - 10 hours	[ ]
More than 10 hours	[ ]

22. What video systems do you use? (Check all that apply)

Nintendo	[ ]
Super Nintendo	[ ]
Genesis	[ ]
Sega CD	[ ]
Sega Saturn	[ ]
Jaguar	[ ]
Home Computer	[ ]

Other *(specify)* ____________________

23. For those video systems that you use, do you use the controller that came with that system? *(If "No", please specify)*

	Yes	No
Nintendo	[ ]	[ ] ____________
Super Nintendo	[ ]	[ ] ____________
Genesis	[ ]	[ ] ____________
Sega CD	[ ]	[ ] ____________
Sega Saturn	[ ]	[ ] ____________
Jaguar	[ ]	[ ] ____________
Home Computer	[ ]	[ ] ____________
Other	[ ]	[ ] ____________

24. How old were you when you started playing video or arcade games? ____________years

25. Have you ever been motion sick (for example: seasick, carsick, airsick, trainsick, etc.) ?

Yes [ ] No [ ]

If YES, explain. ____

____

____

26. Have you ever been motion sick in a tank?

Yes [ ] No [ ]

If YES, explain. ____

____

____

27. How susceptible are you to motion sickness?

Extremely	[ ]
Very	[ ]
Moderately	[ ]
Minimally	[ ]
Not at All	[ ]

Appendix C

Motion Sickness Questionnaire

ISTRUCTIONS: For each item listed, place an "X" in the box to rrespond to HOW YOU FEEL AT THIS MOMENT. PLEASE ANSWER 'ERY ITEM.

Training ____ run no.
Testing ____ run no.

	Not at All	Slight	Somewhat	Moderate	Quite a Bit	Extreme
Generally uncomfortable	☐	☐	☐	☐	☐	☐
Tired	☐	☐	☐	☐	☐	☐
Depressed	☐	☐	☐	☐	☐	☐
Sleepy	☐	☐	☐	☐	☐	☐
Headache	☐	☐	☐	☐	☐	☐
Dizzy (with eyes closed)	☐	☐	☐	☐	☐	☐
Dizzy (with eyes open)	☐	☐	☐	☐	☐	☐
Disoriented	☐	☐	☐	☐	☐	☐
Sweaty	☐	☐	☐	☐	☐	☐
Faint	☐	☐	☐	☐	☐	☐
Aware of my breathing	☐	☐	☐	☐	☐	☐
Nauseous (Sick to stomach)	☐	☐	☐	☐	☐	☐
Burping	☐	☐	☐	☐	☐	☐

	Not at All	Slight	Somewhat	Moderate	Quite a Bit	Extreme
4 Hungry	☐	☐	☐	☐	☐	☐
5 No appetite	☐	☐	☐	☐	☐	☐
6 Chills	☐	☐	☐	☐	☐	☐
7 Blurred vision	☐	☐	☐	☐	☐	☐
3 Decreased salivation (dry mouth)	☐	☐	☐	☐	☐	☐
9 Increased salivation	☐	☐	☐	☐	☐	☐
) Hot flashes	☐	☐	☐	☐	☐	☐
1 Clammy	☐	☐	☐	☐	☐	☐
2 Vomiting			YES ☐	NO ☐		

Thank you

Appendix D

Post-Run and Post Test Questionnaires

Run #: __________

POST-RUN QUESTIONNAIRE

Name: ___________________________________ Date: _______________

Based on your experience using the control ***during this past run,*** *please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.*

1. How easy or difficult was it to slew quickly and accurately on target with the thumb control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. How easy or difficult was it to maintain your crosshairs on target with the thumb control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

Run #: __________

POST-RUN QUESTIONNAIRE

Name: ________________________________ Date: ______________

Based on your experience using the control ***during this past run,*** *please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.*

1. How easy or difficult was it to slew quickly and accurately on target with the displacement yoke control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. How easy or difficult was it to maintain your crosshairs on target with the displacement yoke control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

POST-TEST QUESTIONNAIRE

Name: ______________________________ Date: ______________

Please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.

1. Did the gloves interfere with your ability to acquire or track targets with the thumb control?

Not at All	Sometimes	Not Sure	Often	All the Time
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. By comparison to the control you normally use for tank gunnery, how easy or difficult was it to acquire and track targets with the thumb control?

Much Easier	Somewhat Easier	No Difference	Somewhat More Difficult	Much More Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

3. Is there something that you would change about the control that you used during this study that would improve your ability to acquire and track targets?

____

____

4. Is there something that you would change about the Nomex gloves that would improve your ability to acquire and track targets?

____

____

POST-TEST QUESTIONNAIRE

Name: ______________________________ Date: ______________

Please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.

1. Did the gloves interfere with your ability to acquire or track targets with the displacement yoke control?

Not at All	Sometimes	Not Sure	Often	All the Time
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. By comparison to the control you normally use for tank gunnery, how easy or difficult was it to acquire and track targets with the displacement yoke control?

Much Easier	Somewhat Easier	No Difference	Somewhat More Difficult	Much More Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

3. Is there something that you would change about the control that you used during this study that would improve your ability to acquire and track targets?

____

____

4. Is there something that you would change about the Nomex gloves that would improve your ability to acquire and track targets?

____

____

Appendix E

Safety Release

AMSTE-ST (385-16b)

27 FEB 1990

TEC File

MEMORANDUM FOR Commander, U.S. Army Tank Automotive Command, ATTN: AMSTA-RYA (Al Reid)

SUBJECT: Safety Confirmation for TACOM Ride Motion Simulator (RMS)

1. Reference:

a. Memorandum, HQ TACOM, AMSTA-RYA, 6 Feb 90, subject: Request for Safety Certification of TACOM's Ride Motion Simulator.

b. TACOM RD&E Center Report No. 13470, Safety Assessment of TACOM's Ride Motion Simulator, Warren, MI, Jan 90.

c. TACOM RD&E Center Report No. 13469, System Hazard Analysis of TACOM's Ride Motion Simulator, Warren, MI, Jan 90.

d. TACOM RD&E Center Report No. 13464, User's Manual for the Ride Motion Simulator, Aug 89.

e. TACOM RD&E Center Report No. 13150, Structural Analysis of TACOM Ride Simulator Contract Number DAAE07-84-R047, Warren, MI, Apr 86.

f. Memorandum, HQ TACOM, AMSTA-RYA, undated, subject: Explanation of Accumulators on Ride Motion Simulator.

2. BACKGROUND. TACOM has requested (ref 1a) this headquarters to assist them in reactivating the capability to do research in dynamic, vehicular crew-station design. The ride motion simulator has been dormant for about 7 years, since TACOM was told the system had never been safety "certified." No injuries were reported in the 15-plus years of operation prior to 1982 when test operations were halted. This safety confirmation letter, along with actions by the TACOM Human Use Committee, will again allow use of the RMS.

3. SCOPE. This Safety Confirmation pertains to the operation of the RMS, to the soldier riding the seat of the RMS, and to the console operator. It does not address maintenance on the system; maintenance is governed by OSHA and AMC regulations and the maintenance procedures for the system. A safety confirmation on these procedures is not required as soldiers will not perform system maintenance.

4. LIMITATIONS:

a. Operate the system in accordance with the user manual (ref 1d).

b. Operate only at 1500 psi hydraulic pressure or less, per reference 1b, page 21, and reference 1c, pages 10 and 20.

AMSTE-ST
SUBJECT: Safety Confirmation for TACOM Ride Motion Simulator (RMS)

c. Use only with Human Use Committee (HUC) concurrence on the individual test or similar class of tests.

d. For each new seat/console/instrument panel/system-under-test combination do at least an abbreviated system hazard analysis to assure that structural strength is adequate and that the test subject will not be injured by accidental contact with the test structure. Have your Safety Office concur with the analysis; this headquarters does not have to review each test set-up.

5. Point of contact at this headquarters is Mr. William C. Kietzman, AMSTE-ST, wkietzm@apg-emh1.apg.army.mil, AV 298-2035/3935.

FOR THE COMMANDER:

Roger J. Lerwill

ROGER J. LERWILL
Chief, Safety Office

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